

*Conservation Tillage  
and Cropping Innovation  
Constructing the New Culture of Agriculture*

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## *Constructing the New Culture of Agriculture*

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# Foreword

Almost universally, scientists and technologists judge their accomplishments by their potential to change the status quo. Most often, they are disappointed when not much happens to the status quo, or when the changes are not the ones they anticipated. The problem is that scientists work with technical changes that seem obviously better to them but that may be perceived by the public in general, or their clientele specifically, in an entirely different light.

No-tillage and related forms of conservation tillage are probably perfect examples of this tendency. Although early trials began in the 1950s, and serious research work began in the 1960s, the general adoption of these new methods of farming was much slower in coming. At the University of Kentucky, there still exists our original long-term experiment, now entering its thirty-first year, which has been seen by thousands of farmers. It is doubtful that any one of these thousands rushed home after the field day visit and changed his farming system. On the other hand, this experiment, along with many others in other states and countries, has played an important role in the slow revolution that has changed tillage and cropping on the farm.

One question is, How did this revolution take place? Another is, Why did it take place at all? The detailed answers to these questions are found in this book. Using examples from the United States, principally Kentucky, which led and still leads the nation in the practice of no-tillage cropping, and Australia, particularly Queensland, the authors present histories and case studies of the innovation of conservation tillage at the farm level. The successes, setbacks, and doubts of the innovators show precisely how and why the tillage revolution occurred.

The cases show that the innovators took the notions of new tillage and crafted innovative systems that worked. For example, I was associated with no-tillage research at Virginia Polytechnic Institute in the early 1960s. All the research was on corn, and the corn was always planted in

tilled pasture. The farming system we envisioned was to increase feed for beef cattle by supplementing their mainly pasture-based feed. That farming system hardly exists and never had much popularity. Instead of supplementing pasture, most farmers simply eliminated it where possible and, for good measure, introduced soybeans and wheat into the rotation. Not a single no-tillage researcher of that era would have guessed that outcome.

So it is with the present: We continue to develop new agricultural technology—precision agriculture might be a good example at the moment—but neither the practical utility nor its ultimate role in agriculture can be foreseen.

This book should open the eyes of technical people on how change really occurs. A good technical idea may or may not be a good practice for a particular farmer. And, even though it be a good practice, it could be too troublesome or uneconomical to adopt. In fact, there is hardly a case where the idea is adopted unchanged; either it is modified slightly or a lot and the resulting farming system may be totally different than that envisioned originally.

Of particular interest to me in this book are the case studies of several Kentucky farmers who developed innovative no-tillage and/or minimum tillage cropping systems. In most cases, I have known these farmers for 30 years and have watched both their successes and their difficulties at close range. The stories the authors tell coincide with what I have observed through the years, and this gives me considerable confidence that they have given an accurate picture of what has happened.

The coming of conservation tillage has resulted in a whole array of tillage systems, which have greater or lesser popularity in a given area, depending on soil and climatic restrictions. These systems of tillage, in turn, have engendered new cropping systems. Freed from the danger of excessive erosion, the tendency has been to grow grain crops in rotation continually where they were once grown in rotation with forage crops. Or, in areas where wheat-fallow was the norm, decrease the proportion of fallow and begin to include some summer crops. The net result has been to increase production, not only per acre but per farm. This book admirably describes how this has occurred.

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# Preface

During the last half of the twentieth century, a major change took place in the preferred way of producing the principal cash grain crops—corn, soybeans, wheat, and certain other crops—in the United States, Australia, and other countries. The change constitutes a revolution in cropping agriculture. The formerly dominant cultural pattern of planting crops in a plowed, cultivated, and finely tilled seedbed has been replaced by varied processes of planting crops in untilled, or minimally tilled, ground. In other words, plow culture, which typified and symbolized agriculture around the world for centuries, has been supplanted in many advanced agricultural economies by what has become known as conservation tillage and cropping agriculture. The new agriculture embodies new knowledge and understanding of soils, the environment, the biology and ecology of economic plants and pests, and ways of managing these elements with new technologies. The result is a new agriculture, which relative to plow culture, is more efficient, more productive, and more conserving of key resources of soil and water.

This is a study of the sociology of the conservation tillage and cropping revolution in the United States and Australia. The principal focus of study is the change in tillage and cropping practices that occurred on farms and in farming communities. In this respect, this is a study of innovation in agriculture. How and why did it occur? What was the process of innovation, the significant events? What were the significant socioeconomic and ecological contextual conditions? It is also a study of the spread of no-tillage in particular in the United States. How did the innovation spread? What were the carriers and advocates of the innovation? What was the pattern of growth? How was the pattern of growth in conservation tillage and cropping affected by various constraints and incentives?

The focus on the sociological aspects of the innovation in conservation tillage and cropping means that numerous other worthy aspects are

neglected or dealt with only superficially. For example, although reference is often made throughout the account to changes in tillage and cropping science and technology, no attempt is made to thoroughly analyze the changes per se. In other words, this is a study of innovation in farming practices, not of the change in agricultural science and technology. Moreover, although reference is often made to the comparative profitability of conservation tillage practices as reported by other scientists and farmers, no attempt is made herein to systematically analyze the relative profitability of conservation and plow agriculture.

This study of the conservation tillage and cropping revolution has been guided by three principal conceptual themes. One is that, regardless of the significance of the novel technologies developed by agricultural scientists or marketed by chemical companies, the innovations of principal significance, those that ultimately drove the new agriculture, were the innovative systems of tillage and cropping constructed by farmers. No-tillage corn, for example, is an organized sociotechnical system of corn production managed by a farmer. Other farmers were attracted by the cropping success enjoyed by these systems innovators and set out to create comparable systems of their own. The new agriculture, in other words, is not simply a new technology of agriculture; it is a new *system of agricultural production* in which the farmer is the key system component. The benefits derive from the use of particular technologies (e.g., herbicides or no-till planters) because they are components of a qualitatively different system of crop production.

The second theme of this study is that these innovative systems of tillage and cropping are social constructions of networks of farmers and professional farm advisors. That is, the innovative systems were not, especially in the initial developmental phase, developed at one time but rather were created piecemeal over a period of years, through innovative trial and adaptation. Although individual farmers constructed innovative systems that they operated successfully, the creative imagination that succeeded in putting the new system together invariably involved several people—farmers and farm advisors, and more remotely agricultural scientists—working together. In this sense, the new agricultural production systems were socially constructed by *innovative networks*.

The third theme guiding the study is that through the spread over time of innovative conservation tillage and cropping systems, the indigenous agriculture for major commercial crops in specific agroecosystems has undergone revolutionary change. The cultural tradition of plow agriculture has been replaced by a new *conservation tillage and cropping agricultural tradition* that is based on a different agricultural science and is organized under different management principles. In some agro-



ecosystems, the new agriculture is now being practiced by the second and third generation. The third generation only fully understands the new cropping agriculture. This is the significance of the conservation tillage and cropping cultural revolution in the United States, Australia, and other temperate regions of the world.

This book has grown out of the authors' long-time interests in problems of soil conservation, but the idea of a comparative study of the innovation of conservation tillage and cropping in the United States and Australia flowered in 1988 while the senior author was on sabbatical leave at the University of Queensland. Our interest initially was in determining the ways in which the process of innovating complex systems might differ due to different historical, ecological, and sociopolitical contexts. This led to in-depth interviews with six farmers on the Darling Downs in Queensland who had constructed conservation cropping systems. We also interviewed soil conservation and extension officers who had been involved in programs to promote and spread stubble mulching and/or zero-tillage techniques as well as representatives of machinery and chemical companies. This program of data collection was followed up in 1992, while the junior author was on sabbatical leave at the University of Kentucky, with in-depth interviews with eight tillage innovators in Kentucky as well as with a number of Cooperative Extension Service specialists and researchers who had been engaged in research and extension work with no-tillage in Kentucky. Since then, we have conducted follow-up interviews with most of the original respondents and other key informants. The study also has benefitted substantially by the acquisition of tillage data obtained and published by *No-Till Farmer* annually from 1972 through 1997. Data for 1998 were obtained from the Conservation Technology Information Center. This enabled us to analyze trends in tillage utilization over the past quarter of a century.

C. M. C.

S. C.

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The authors are foremost indebted to the farmers in Kentucky and Queensland who have taken us into their confidence, often on several different occasions, and willingly shared their feelings, situations, and experiences in constructing their conservation tillage and cropping systems. Their commitments and ingenuity throughout the long innovative process have continually amazed us. This indebtedness also extends to the Soil Conservation officers, Extension Specialists, university researchers, and representatives of Monsanto and ICI Australia who have shared their insights and experiences in the development of conservation tillage practice. Needless to say, without their cooperation, this book would not have been possible, and we wish to express our profound thanks to all of our informants. Our hope is that we have kept the trust given us in accurately reporting and interpreting their motivations, goals, and actions.

We owe a special debt of thanks to Mr. Frank Lessiter, Editor, *No-Till Farmer*, who graciously supplied copies of the reports of tillage practice acreage collected and published annually between 1972 and 1997, and we thank the Conservation Technology Information Center for supplying tillage data for 1998.

The study would not have been possible without the continued support of the University of Queensland, the former Department of Agriculture, and now the School of Natural and Rural Systems Management and the University of Kentucky, College of Agriculture, Department of (Rural) Sociology, which made research time and financial support repeatedly available for this project. We especially want to thank Nancy Strang and Bruce Gage, Department of (Rural) Sociology, University of Kentucky, who developed the figures and maps, and Aneen Boyd who typed the tables for the manuscript.

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# 1

## Introduction

*In southwestern Kentucky, soil erosion and frequent cool and wet springs were recurrent problems for grain grower Harry Young, Jr. He hated to see the rills and gullies develop on the bare ground, which had been plowed and cultivated in the fall and spring, in preparation for late April corn planting. If the spring was unusually wet, plant bed preparation—plowing, discing, harrowing—would be delayed. Cultivation time always limited the number of acres that could be planted before the fifteenth of May. Average corn yields dropped each day that planting was delayed beyond that date. Mr. Young, and other farmers in the area, thus had a double incentive to develop better planting technology: to eliminate bare fallow ground and to plant corn in a timely manner.*

*Having been an Extension Specialist, Mr. Young had learned that leaving plant residue on fields after harvest reduced soil loss, and he had used 2,4-D herbicide in fence rows to control weeds. Through his extension contacts, he learned about successful attempts of scientists to use herbicides to control weeds at planting time. In 1959, he tried using one of the new preemergent herbicides to plant corn without tillage, but poor weed control ruined the corn crop. As the 1962 planting season approached, Mr. Young decided to try a newly released preemergent herbicide—atrazine—to suppress weeds prior to planting corn on 0.7 acre, which had not been tilled since harvesting soybeans the previous year. To plant in the untilled ground, Mr. Young added weight to his planter to force the coulters into the ground where the corn seed could be deposited. That fall, the yield on the untilled field compared favorably with that on his conventionally tilled fields, confirming the practicality of the principle of no-tillage planting, and encouraging Mr. Young both to expand his experiments with no-till planting and to promote it with other farmers (Phillips and Young 1973). It was the first successful farm trial in the Midwest of a radically different approach to planting corn crops (fig. 1.1).*

“Beginning in Jefferson’s time, the cardinal image of American aspirations,” writes Leo Marx (1964, 141), “was a rural landscape, a well-ordered garden magnified to continental size.” The bucolic image of rolling pastures, neatly trimmed fields with ordered rows of corn and



Figure 1.1. No-tillage historical marker in Christian County, Kentucky. (Courtesy of Robert Bateman)

waving fields of golden grain, a few cattle, and here and there a farmstead still remains our dominant image of a lovely countryside. The image is not inert and lifeless. The picture gains its dynamism from the fact “that down to the twentieth century the imagination of Americans was dominated by the idea of transforming the wild heartland” of America into this kind of a well-ordered landscape (Marx 1964, 141). Quite by contrast, the wilderness image held in earlier times was not the benign and inviting place that we imagine today (Thoreau 1939); the wilderness for eighteenth and early nineteenth century people was an unproductive and fearsome place, the haunt of savages and wild beasts.

Settlers of the American wilderness aimed to create a civilized society and make the wilderness productive. Thus, the farmer patiently hewing the forest and breaking the sod was a splendid instrument of civilization and national purpose. The chief tools of his craft—the axe and the plow—were key weapons in a much larger, transcendent struggle than the mere preparation of open, sun-filled fields of wheat and corn. As civilization’s armament, they bore the moral force of the sword Excalibur, enabling the farmer to fulfill America’s destiny.

Plows were adapted to frontier conditions, and they subsequently developed into the steel moldboard plow in America, the stump-jump plough<sup>1</sup>

in Australia, and the disc plow, which were all key to this real-life drama (Pratley and Rowell 1987). On both continents, the plow was the farmer's primary tillage instrument for more than a century.<sup>2</sup> Other cropping equipment—the tined and disc harrows, and various types of planters—were complementary to the plow, developed to keep “broken” ground weed free and to till the soil for planting. Farmers felt, moreover, that in turning the ground they were aiding aeration, water infiltration, and plant root penetration while lifting nutrients to the surface<sup>3</sup> and depositing plant residue below it to decay and provide nutrients for next season's crops. A clean and finely tilled field, clean fence rows, and straight rows of corn were the stamp of a farmer who was both skillful and good.

But, wind and rainfall ravaged such unprotected fields, defiling the landscape and tarnishing the farmer's heroic image. To restore that image, a portrait of a different landscape and a different technology of cultivation would be necessary. Help was on the way. As the nineteenth century came to a close, U.S. Department of Agriculture scientists began to advocate the retention of crop residues to minimize the effects of destructive natural forces (Tabor 1953).<sup>4</sup> But, farmers did not possess either the machinery or the knowledge of “stubble” farming, and because yield losses were gradual, the need for change was not compelling; no new vision of a different “civilized” landscape had been constructed to serve as moral guide and source of pride of alternative farming practice. It took another three decades for much progress in this regard to be made.

Although studies of soils and the concern with soil erosion increased in the early decades of the twentieth century (Bennett 1921, 1939; Pratley and Rowell 1987), little change in either public policies or farming practices occurred until the 1930s. Then, primarily due to the dramatic impact of the dust bowl and New Deal activism, federal funding of research and action programs to control erosion was established in 1935 (Rasmussen 1982; Swanson 1986). Late in the decade, as part of its erosion control program, the Soil Conservation Service initiated research on stubble-mulch farming at several locations on the high plains (McCalla and Army 1960). Research in the United States and Canada soon demonstrated the effectiveness of crop residue in reducing water and wind erosion (Bennett 1942; Duly and Russel 1939, 1942) and provided objective information on the stubble-saving efficacy of various kinds of tillage machines—disc harrows, disc plows, and duckfoot cultivators (Duly and Russel 1942; Shedd and Norton 1943; Morehead 1942). In South Australia, research on the stabilization of light soils enabled Callaghan and Millington (1956) to recommend the retention of stubble, the use of cover crops, and autumn planting of cereal rye.

As yet, however, there was no positive economic rationale for change in farming practice and no generally accepted method of maintaining stubble while controlling weeds in various crops. But, the vision of the desirable way of farming was beginning to change. The destructive consequences of conventional tillage were increasingly contrasted with beneficial results of “natural” (Faulkner 1943), humus (Sykes 1949; Seifert 1952), or organic (Rodale 1945; Bromfield 1946) farming methods. The emphasis was on an integrated or “wholistic” perspective of farming.

Of equal importance, the image of clean, fine-tilled cultivation as the hallmark of civilization’s progress and a bucolic rural life was changing. The existence of swamp and forest no longer aroused a sense of foreboding, of untamed wildness. In his widely read *Sand County Almanac*, the naturalist-farmer, Aldo Leopold, decried “clean” cultivation and “good” (conventional) farming methods in general:

[F]arm neighborhoods are good in proportion to the poverty of their floras. My own farm was selected for its lack of goodness and its lack of highway; indeed my whole neighborhood lies in a backwash of the River of Progress. My road is the original wagon track of the pioneers, innocent of grades or gravel, brushings or bulldozers. My neighbors bring a sigh to the County Agent. Their fencerows go unshaven for years on end. Their marshes are neither dyked nor drained. . . . For a decade I have kept, for pastime, a record of the wild plant species in first bloom [in the backwoods and in the university and city.] It is apparent that the backward farmer’s eye is nearly twice as well fed as the eye of the university student or businessman. . . . The shrinkage in the flora [in the urban environment] is due to a combination of clean-farming, woodlot grazing, and good roads. (Leopold 1949, 46–47)

Clearly, a clean plowed field no longer would be universally acclaimed as civilization’s hallmark. The awesome destruction wrought by wind and summer rainstorms on fine-tilled ground had become widely recognized. By the 1950s, grain farmers in the summer rainfall areas of both the United States and Australia were ready to try new practices of planting and cultivation. An increasing number of ordinary farmers were beginning to envision a remodeled landscape in which terraces, strip crops, and the residue from the year’s harvest were left on the surface to decay and to shelter the fallow ground from seasonal storms.

This awareness of the positive effects of mulching with field crops was becoming more widespread (Bromfield 1946; Faulkner 1943, 1952; Rodale 1945). Bromfield (1950) eloquently stated the power of mulching to restore the despoiled landscape:

The hills on the Bailey place provided the most striking example of the power of trash mulching in the prevention of erosion, the creation of organic material and topsoil, and the change, economically speaking, from zero production to high-quality grass and legume forage in terms of silage, hay and pasture.

These hills had been corned out, farmed out, pastured out, sheeped out and abandoned. On them there remained not a grain of topsoil, and the vegetation covering them consisted of broom sedge, poverty grass, wire grass, sorrel, golden rod, wild aster and here and there a sickly tuft of bluegrass. . . .

[After disking and seeding to rye,] we went into the field with Ferguson tillers and disks and literally chewed the rye stems and the weeds and the roots of both into the surface to a depth of about three or four inches, leaving the trash on top or at best worked in to a shallow depth.

. . . Into the resulting trash mulch we drilled a seeding of alfalfa, brome grass and ladino clover with from 300 to 400 pounds of 3-12-12 fertilizer. Then something miraculous happened. Virtually every seed germinated and within a few weeks the field was green with seedlings. . . . The following year the once weedy, barren hills were covered with a heavy sod, virtually weedless of alfalfa, brome grass and ladino clover, giving us the equivalent of \$90 to \$100 an acre in high quality forage. (Bromfield 1950, 61–62)

In the years following World War II, the idea of saving stubble from the previous crop to reduce erosion and to plant the next grain crop in the lightly tilled residue began to spread, especially in the plains areas. But for tillers of row crops, control of weeds, procedures for restoring fertility, planting in stubble, and doubts about yields were still potent constraints to alternative tillage practices. In fact, the more successful grain farmers became in boosting corn yields through conventional cultivation and heavy applications of nitrogen, the more reluctant they were to try alternative cultivation procedures. Yet, new technological developments rendered such departures more and more possible. The release in the late 1940s of plant growth-regulating chemicals, which had been developed during World War II, stimulated experimental research with reduced-tillage cropping. Succeeding years saw the development and release of a wide range of other chemical weed control agents.

Although Harry Young, Jr., is widely credited with being the first to successfully raise corn without tillage, many farmers were trying various ways of modifying tillage practices (van Es and Notier 1988; Nelson 1997). Young's success, however, created widespread excitement; farmers and agricultural workers came from nearby states and counties to see the successful demonstration trials of no-till corn. With new herbicides



offering the prospect of better weed control, effective planting equipment was the major constraint to widespread no-till practice in the grain-growing region of western Kentucky.<sup>5</sup>

A major breakthrough came in 1966 with the marketing of the Allis-Chalmers, a no-till corn planter. More heavily constructed than conventional planters, it featured a fluted coulter to cut through stubble and open a slot for the planting shear, and a press wheel to close the soil around the seed. On loamy, southwest Kentucky soils, it worked well. By 1970, 35 percent of the farmers in this county had tried no-tilling corn.<sup>6</sup> No-tillage also worked with soybeans planted in wheat stubble, and a new cropping system of three crops in two years became possible. An effective conservation tillage and cropping strategy had been established, and innovative farmers continued development of successful no-till and other conservation tillage systems throughout the midwestern corn belt.

Due to its soil conservation and economic benefits, conservation cropping systems spread widely during the next three decades. By 1998, according to the Conservation Technology Information Center annual survey, crops on 37 percent of the cropland in the United States were grown with conservation tillage methods. No-tillage, the least intrusive tillage system, was used on 5 percent or more of the acreage in 36 of the 50 states and Puerto Rico. Reduced tillage systems have replaced plow tillage systems in the production of nearly all corn, soybean, and wheat crops grown in the United States. The cultural revolution in cropping agriculture is well advanced and continuing to spread.

Although conservation tillage practice developed differently in Australia, the transformation in tillage practice was no less dramatic. The traditional images of the good farmer, with his clean tilled fields, straight rows of corn or sorghum, and waving fields of winter wheat or barley were no less compelling than in the United States. The prevailing tillage practices in the 1950s entailed burning of stubble from winter wheat and barley, so that the ground could be plowed with a moldboard, or a sundercutter, and then maintained weed free by cultivation during the summer fallow. At summer's end, a clean, finely tilled field was ready to plant in winter wheat, barley, or oats. The handling of winter fallow following summer crops was much the same, except that the burning of residue was seldom required.

A rotation from summer to winter crops, or conversely, was typically accomplished by a long fallow from the harvest of the summer crop to the fall planting of a winter crop in the following year. Or, the ground would be fallowed from wheat harvest in early summer to planting of a summer crop the following year, a 12- to 15-month period. To keep the

fields weed free during these fallow periods, five to seven cultivations were required. Not surprisingly, the clean-fallowed fields suffered considerable erosion especially during the strong thunderstorms, which typically occurred in the summer (Chamala et al. 1983).

In the late 1940s, soil conservation officers began to advocate the construction of contour banks and incorporating, rather than burning, the stubble. A decade or so later, soil conservation officers began recommending strip cropping to hold the soil. During the 1970s, farmers began to believe that burning stubble was wasteful and to perceive that the removal of stubble left their fields unprotected. Eventually, both burning stubble and plowing became anathema. But, this point of view was possible only after the acquisition and development of appropriate stubble-mulching equipment for controlling weeds during fallow.

By the mid-1980s, a few farmers were beginning to experiment with a new cropping strategy, called opportunity cropping, which used herbicides to avoid cultivation, retain stubble, and reduce the loss of both soil and soil moisture. The moisture level was monitored to determine whether it was sufficient to justify planting an economic crop. The strategy and methods had been developed in experimental trials by Soil Conservation Branch officers of the Department of Primary Industries in cooperation with chemical companies. A decade later, the tillage innovators had resolved nearly all of the issues surrounding these strategies, and no-tillage, opportunity cropping had become a common cropping system.

## The Study

This study focuses on this revolutionary change from conventional plow tillage agriculture to a conservation tillage and cropping agriculture by farmers in the United States and Australia. Plow tillage agriculture dominated crop production throughout the modern world at the turn of the twentieth century. Its goals and methods were unquestioned; its routines marked the yeoman and launched the seasons. And, it exposed the soil to the erosive forces of wind and water contributing to the massive waste of this precious resource.

In the decades after 1950, however, plow culture lost its formerly unchallenged sway to new, revolutionary systems of conservation tillage and a new culture of conservation farming. The new tillage strategies have been variously labeled minimum tillage, wheel-track planting, plow-plant, strip tillage, and zero- or no-tillage or direct drilling. Although we focus in this book on the innovative construction of these tillage methods by farmers, these methods are only the most recent of a

panoply of methods introduced in this century to save soil resources. The broad range of these techniques highlight the growth of conservation agriculture during this period.

A new and broader concern with the environmental well-being is an integral part of the new agriculture. Farmers have become concerned with plant and pest ecologies as well as with the quality of water and wildlife. A notably different landscape—fields that are always covered with growing crops or crop residues—is an essential part of the tillage revolution. This broader environmental concern heralds a twenty-first-century agriculture that differs radically from the agriculture aiming to civilize the wilderness that was prevalent at the dawn of the twentieth century.

One part of the story presented in this book focuses on the remarkable innovativeness of networks of farmers and farm advisors who constructed radically new farmer-managed production systems. In doing so, they led the advance of the revolution in tillage and crop agriculture, which has taken place during the second half of the twentieth century and is the second part of the story. The innovative farmers invariably began with a relatively labor-intensive—but effective—mechanical system of weed control and plant bed preparation in crop and livestock farming systems. They ended with a variety of more complex, soil and plant management systems. They also constructed new farming systems. While cropping expanded, the role of livestock either became smaller or substantially different.

This study is guided by five key propositions:

1. Conservation tillage systems (e.g., mulch tillage) are farmer-managed sociotechnical crop production systems.
2. These sociotechnical systems are innovative social constructions (i.e., new patterns of decision making and technical behavior) of farmers and professional farm advisors in local social networks linked to global networks.
3. The process of diffusion, or expansion, of conservation tillage/cropping systems is initiated by institutional (“change”) agents by forming new innovative local networks.
4. Change in a tillage master frame and local network is initiated when a farmer experiences unresolved dissonance, or dissatisfying imbalance, in his goal state(s) from operation of his tillage system, resulting in repetitive cycles of action-learning.
5. In that conservation cropping has gained moral legitimacy on the basis of a radically different view of the farm environment (including its soil and water resources and the goals of farming), the diffusion of con-

ervation cropping is the hallmark of a sociocultural revolution in cropping agriculture.

The conceptual perspective guiding the study is presented in chapter 2. The theoretical perspective is that the new tillage systems (e.g., no-tillage) are social and cultural products. Technologies are social products because they are created by human beings to increase their efficiency and effectiveness in attaining desired ends (Stinchcombe 1983; Bijker et al. 1987).

The process of technical invention followed the course of constructed innovation described by Latour (1987), Bijker et al. (1987), and others. Conservation tillage systems are social constructions in not one but in two respects. Not only is the tillage system, which a farmer uses, constructed by him in order to plant and grow a particular crop, the goal itself—the modification of the biophysical environment for growing the crop—is a social, and ultimately cultural, construction (Callon 1987; Greider and Garkovich 1994). From a socioecological point of view, *conservation cropping is a strategy for using particular (tillage) techniques to construct a fertile landscape continuously covered by growing crops or crop residues*. Compared with a conventionally tilled fallow (landscape), the conservation-tilled fallow conserves soil and moisture and has better soil health.

The innovation of new tillage and cropping systems took place in the context of a dominant plow culture whose practices were not only accepted as efficient and efficacious but also socially and morally proper. It rested on unquestioned principles of land and crop management. Plowing enabled the yeoman to provide sustenance for himself and his family. It certified his manhood and validated his role in community. His work inaugurated seasonal rhythms. Chapter 3 analyzes the historical development of plow culture, the dominant technical, social, and cultural order against which the new principles and practices of weed control and plant bed preparation were socially constructed and won acceptance.

Changes in international markets and national policies for agriculture in the post–World War II period created a fertile context for agricultural innovation and rapid change in agricultural technology. Market prices provided incentives to farmers to increase farm capital and become more productive. Conservation programs heightened concern with protection of soil resources. The expansion of national research and extension capacities increased the flow of technology and educational support to farmers. New weed control and tillage technologies became part of the changing technological context. The changing socioeconomic context of American and Australian agriculture, in

which the revolution in conservation tillage took place, is discussed in chapter 4.

The new tillage and cropping systems were not constructed by isolated farmers. In every case, as we show in chapter 5, the innovative farmers were participants in innovative networks. The building or establishment of *social networks* of agency advisors and farmers has been the essential mechanism facilitating the innovation process on the farm. The innovative local networks were linked with larger networks of supporting agencies, involving researchers, policy makers, and farm supply companies. These networks of support were new in the sense that their functional roles were redefined. That is, the new system technologies required new kinds of inputs as well as new knowledge and skills, and the provision of these inputs redefined the relationships to input suppliers and in some cases the selection and development of new provider relationships. Similarly, the establishment of new relationships with sources of technical expertise, such as soil conservation and agricultural extension agents, is often required.

Chapters 6 and 7 provide case histories of the processes of *action-learning* (i.e., innovation over time) of conservation tillage and cropping systems in the United States and Queensland, Australia, respectively. System innovation, unlike innovation-adoption of individual technologies, involves repetitive processes of action-learning. The sociopsychological process starts with dissatisfaction with an existing situation and is followed by efforts to construct new technical operations to resolve the perceived imbalance. In chapter 6, stories are presented of the successive cycles of action-learning of Kentucky and Iowa farmers in the construction of no-till and minimum-till cropping systems. The case histories are based on data obtained through personal interviews and published sources. A similar method is used in developing the case histories of conservation-cropping innovation in Queensland, Australia, which are presented in chapter 7. The cases in both countries demonstrate that the social construction of the innovative systems took place over a period of several years, occasionally a decade or longer. Inasmuch as most farmers constructed the new tillage and cropping system a step at a time, the innovative process was “evolutionary” (Nowak and Korsching 1985), but in each case the process ended with the creation of a radically different (i.e., revolutionary) system of cropping. It was revolutionary because the farmer shifted from conventional farming technologies to different tillage techniques—often no tillage at all—to usually a different cropping system, often a new farming system, a new vision of a desirable farm landscape, and a new identity as a farmer.

Using the systems innovators as exemplars, change agents established networks of innovative farmers in other areas. In Kentucky, as is shown in chapter 8, no-tillage spread quite rapidly at first, but this initial burst was followed by a period of retrenchment as farmers confronted difficult weed control and other constraints. Finally, in the past decade, there has been a renewal of rapid growth in no-till cropping. In Queensland, the institutional strategy for diffusing conservation tillage was much the same. The comparative analysis of the spread of conservation tillage systems is presented in chapter 8.

Innovative conservation tillage and cropping systems have spread to, or more accurately have been reinvented (Rogers 1983), in all states in the United States (except Hawaii), in all the Australian states, and to many other countries. Annual tillage practice surveys by *No-Till Farmer* and the Conservation Technology Information Center show that the growth of no-tillage cropping systems in the United States has been episodic rather than curving smoothly upward. For the most part, the utilization of this particular cropping system spread outward from the core states where it originated to peripheral areas. The analysis in chapter 9 will show that the pattern of growth of no-tillage and reduced-tillage cropping systems generally has been affected by various policy, market, and institutional factors as well as by environmental social movements.

The in-depth understanding of the innovation of conservation tillage and cropping systems and their diffusion in the United States and Australia provides valuable lessons for institutions engaged in promoting and assisting system change. The implications of this historical experience for conservation policies and the institutions of research and extension are discussed in chapter 10. The process of diffusion, as this study indicates, differs substantially from the classical theory of the diffusion of innovations (Rogers 1983). The principal difference in our view is that because a practicing farmer and his farm are the core of a conservation tillage system, rather than simply of a particular machine or the chemical herbicide, diffusion takes place by the communication of a model of a tillage cropping system that individual farmers acquire and use as a basis for reconstructing a satisfactory management system of their own. Invariably, this reconstruction, or reinvention, is accomplished by networking with knowledgeable advisors and other innovative-minded farmers. Historically, professional advisors most often have provided the principal impetus to innovation of conservation tillage systems.

As the twenty-first century begins, conservation cropping systems have become the dominant agriculture of the major grain crops in the

United States and, perhaps, Australia.<sup>7</sup> As we emphasize in chapter 11, the decline and replacement of plow culture represents a sea change in the culture of agriculture. The unquestioned centerpost of farming operations for generations of farmers and farming communities up to the middle of the twentieth century has become anathema to an ecologically minded public and to farmers themselves. The latter have a different image of themselves as responsible stewards of valued resources, engaging in sustainable agriculture production in a remodeled landscape of their own making. The future of the conservation tillage and cropping revolution and its impact on farmers, society, and culture are the subject of the final chapter.

## Notes

1. The American “plow” and English and Australian “plough” will be used interchangeably throughout this book.

2. In late nineteenth-Century Australia, digging ploughs and subsoiler ploughs began to replace the moldboard in areas with heavy clay soils, which tended to become cloddy when turned (Pratley and Rowell 1987).

3. Research in the late nineteenth and early twentieth centuries failed to demonstrate any general benefit of deep plowing (Pratley and Rowell 1987).

4. In South Australia, the value of surface cover in reducing movement of the light, Mallee soils was initially demonstrated by Hore (1940, cited by Pratley and Rowell 1987).

5. In other areas of the corn belt, soil borne insects, poorly drained soils, the cooling effect of mulch on northern soils, and management constraints slowed the practice of zero tillage (Phillips 1978).

6. This estimate is based on a small sample survey of Christian County farmers. See Choi (1981).

Prior to attempting no-tillage or stubble mulching, some farmers in Kentucky and Australia initially tried the new systems of farming by hiring a farmer who had the equipment to apply herbicides or to plant a few acres to see whether it would be successful on their properties (Choi and Coughenour 1979; Chamala et al. 1983).

7. At the present time, data are not available with which to assess the extent of utilization of conservation cropping systems in Australia.

## 2

# Conceptualizing System Innovation: Social Construction of Conservation Tillage and Cropping

*[Each person is] conscious of the world as consisting of multiple, [meaningful] realities. . . . [T]he reality of everyday life . . . [is] the paramount reality . . . and taken for granted as reality . . . until its continuity is interrupted by the appearance of a problem. . . . When this happens, . . . [the person by conscious processes] seeks to integrate the problematic sector into what is already unproblematic.*

—Peter L. Berger and Thomas Luckman (1966, 21, 24)

*The idea of making a plastic by chemical synthesis simply did not . . . occur to [the Celluloid chemists because] the technological frame of synthetic plastics was not yet in existence. . . . Bakeland worked to an important degree within the Celluloid frame and he worked equally importantly to some extent . . . in another technical frame electro-chemical engineering. [His interest in other fields of application led to a long investigation] to control the violent chemical condensation reaction . . . [to produce bakelite].*

—Wiebe E. Bijker (1987, 170, 171)

The prototypical situation with which this study is concerned is the farmer engaged in broad-acre crop production. For some, grain production may be the only enterprise, but, often, especially during the 1960s in Kentucky and Queensland, crop production was combined with livestock production. In such cases, the production of grain (e.g., corn, soybeans, sorghum, barley, wheat, or sunflowers) varies from a relatively small to a substantial part of the total farm enterprise. Regardless, in his annual round of work, the farmer after harvesting a crop has to prepare the field to plant the next crop. Under a conventional tillage and cropping system, this usually includes a period of several months when the field is managed as fallow ground. Our objective in this chapter is to



outline a conceptual perspective for understanding how many of the farmers in the United States and Australia made a radical change during the past four decades from the conventional, everyday reality of plowing and cultivation to a cultural reality of conservation tillage and cropping.

The activities with which the farmer accomplishes the land management ends of preparing to produce a crop flow from his knowledge of a particular field and the prevailing climate and economic conditions. Using available technology, the farmer engages in tillage activities, which from his point of view, prepare the land for the crop(s) he intends to grow. In part, this task may be defined as a problem of increasing soil nutrients and sufficiently improving soil structure to produce a particular crop. Inevitably too, he seeks to avoid waste of these soil resources by noneconomic plants during the fallow period.

As a result of a farmer's tillage activities, the postharvest field takes on the appearance of a desirable plant bed for the anticipated grain or forage crop. Under *conventional tillage* with a plow and disc, the typical field soon takes on the appearance of "clean fallow." With a *mulch* or *minimum tillage system*, the aim, while adding necessary nutrients and controlling weeds, is to retain the residues from the previous crop in the fallow period as long as possible. These alternative landscape<sup>1</sup> management systems secure significant cost-reduction benefits, as well as soil and moisture savings and improved soil structure. Although these socioeconomic, ecological, and esthetic aims are not the only ones that a farmer may have in choosing tillage techniques, they are invariably present in his decision making and are the principal foci of this study.

Some aspect of landscape management, whether increasing fertility, controlling weeds and disease vectors, saving soil and moisture, or planting and nurturing a crop, is seldom far from a farmer's conscious attention. It is an ordinary part of a farmer's everyday reality, his "lifeworld" (Berger and Luckmann 1966). A farmer's landscape management decisions and activities are made in the context of the history of his past farming decisions and activities and of the farm, with its particular topography, soils, flora, and prevailing climate.

Two features of farm life are crucial to its understanding in our view. First, it is orderly (i.e., organized) in the sense that there is a degree of consistency in the characteristics of the particular farm, persons, and groups involved and their ongoing activities. There is a predictable rhythm to farm life, including the annual variation in the biophysical environment and in the annual patterns of social and economic activities. The second important feature is that this social order of farm life exists because of the controlling activities of the farmer and the family

relative to the variability of biophysical environment on the one hand and the socioeconomic environment on the other hand. In this respect, it is a social order constructed to enable the family to make a living.

The orderly pattern of farming activities and the farm landscape by a farmer are the defining characteristics of a farming system. When the forces outside the farmer's control—weather, prices, policies, etc.—change the balance of opportunities and constraints, thereby reducing his ability to attain farming goals, the farmer is able to make adaptive changes that reduce the risk of unfavorable, and increase the probability of favorable, outcomes. In this respect, the farming system is adaptive.

At a higher level of abstraction, the activities of the farmer's everyday life are orderly because of the symbolic frames—the sets of symbols—through which he views the world and which he uses in controlling farming activities (Goffman 1974; Berger and Luckman 1966). These symbolic frames are elements of local farming culture, which typically a person acquires as a child through socialization into adult farm life.

A tillage frame for crop production and farm landscape management is one of the many socially constructed (cultural) frames that give meaning to a farmer's everyday life.<sup>2</sup> As Bijker (1987) emphasizes, the frame exists “between” farmers, farm advisors, and farm supply agents as well as ordinary members of the community, uniting them in their related activities. With the tillage frame, each farmer still must construct an operational tillage system to manipulate his farm landscape for his crops. To do this he must acquire implements and learn to use them to control weeds and prepare ground, and he must add nutrients in the right way and know how to plant a particular crop.

Over the past four decades, farmers have constructed new, conservation tillage and cropping systems,<sup>3</sup> to gain better control of the farm landscape for crop production. The conservation tillage—a term that encompasses minimum or mulch tillage, no-tillage, stubble mulching, and the like—of a crop is an innovation in the sense of a qualitatively different way of believing and behaving; a new paradigm (Kuhn 1970). Compared with plow culture, conservation tillage frames involve qualitatively different beliefs about the environment and ways of managing it to produce a crop. As we will see, the conservation tillage frame is more complex than the plow tillage frame.

This innovative tillage and cropping frame was not developed all at once either by farmers or indeed by scientists; instead, it was constructed by farmers, scientists, and farm advisors over a period of years (van Es and Notier 1988; Nowak and Korsching 1985). Although the various component technologies as well as *notions* of conservation tillage systems mostly originated in the work of scientists (e.g., see Shear 1985; McCalla

and Army 1960; van Es and Notier 1988), we will show that the no-tillage frame in particular, including several operational tillage systems, were put together (i.e., socially constructed) by networks of innovative farmers, farm advisors, and agricultural scientists. Conservation tillage and cropping frames are based on a new science of agriculture and have radically different environmental goals. In this sense, there is a new culture of agriculture.

The crucial significance we attribute to innovative networks of farmers and farm advisors in creating the conservation tillage frames does not gainsay the critical importance scientific research and technology development, especially of new chemical herbicides, and new machines; rather, the innovative networks include both scientists and farmers (van Es and Notier 1988). Each of the new technical artifacts, with its applicable human activities, is an innovation in its own right with its own history of development (e.g., 2,4-D) (Peterson 1967). The knowledge of soil, mulch, and plant interactions generated by agricultural scientists together with these new technical innovations contribute to a new conceptual perspective—a new technical frame (Bijker 1987)—for management of soils and planting crops, enabling farmers to construct innovative conservation tillage operating systems. Put otherwise, although individually and collectively these new chemicals, machines, and research information are essential components of conservation tillage, by themselves they do not delineate a successful tillage and cropping system used by a farmer or several farmers. It is the qualitatively different tillage cropping frame and the new operative systems, which farmers have constructed, that are the significant tillage innovations on which this study focuses.<sup>4</sup>

### Constructing Frames and Systems

From a cognitive perspective, the farmer's tillage and other farming activities are relatively stable and predictable because of the cognitive structures—*frames* (Goffman 1974) or *schemas* (Shaw and Hazelett 1986; Markus and Zajonc 1985)—that guide his activities. A frame consists of the taken-for-granted attitudes and beliefs, rules, classifications, and scripts that organize human perceptions and actions. These cognitive elements constitute a filter through which the perceptions of daily farm life become real and are recognized as important, or unimportant, to further thought and action. The beliefs, attitudes, and other symbolic meanings derive from the prototypical features (Rosch 1978), origins, essences (Lakoff 1987; Keil 1987), social contexts, and ordinary uses of social objects (Keil 1987). Analysis of the way in which the various

objects of daily life come to have meaningful significance provides understanding of the way in which new beliefs, attitudes, and meanings of a new tillage system—conservation tillage—was constructed (developed) by farmers.

*Resources, tools, and sources* are three abstract classes of objects that are especially relevant to the study of tillage and cropping frames and systems. Any aspect of the human or natural environment (e.g., soil) that can be used to produce something of value is a resource (Stinchcombe 1983; Bennett 1982). The concept of resource gathers meaning as the socioeconomic context (e.g., agriculture), origin (e.g., natural or artificial), and purpose (e.g., cropping) further specify the nature of the resource.

Tools are the instruments of techniques. Techniques are tightly coupled systems employing tools. Tools increase the efficiency or effectiveness of human (technical) activities in attaining desired ends (Stinchcombe 1983). One purpose of technique is to enable human users to modify their environments (e.g., to create or enhance a resource). Agricultural resources thus are dependent on the technologies that are available and used in their development and use at a particular time (Coughenour 1984). Boggy land is a “constraint,” rather than an agricultural resource unless, or until, drainage techniques are applied. Moreover, when the plow was the principal tillage instrument, crop residue was a major constraint. It became a resource only when the soil-conserving function of crop residue became known and when tools for controlling weeds while maintaining residue and for planting a crop through surface residue became available.

Tools are developed for specialized purposes. The purposes ordinarily include the environments—natural and social—in which the tool is to be used and the intended result of the tool-using activity. As such, a tool embodies the knowledge and purpose(s) of its maker(s) who include the original developer as well as the user (Latour 1987; Busch 1984). Although most agricultural tools are developed by agribusinesses, a tool and the technical instructions for its use are supplied to farmers by “sources,” including agricultural agents and farm product suppliers. These sources comprise the most important class of human objects in the farm input environment.

*Technologies* are the instructions or specifications for using tools in the performance of a particular task (e.g. planting corn). In other words, a technology is a behavioral script (Fivush 1987). As Fivush (1987, 236) puts it, “a script is . . . a spatially-temporally organized body of knowledge that defines the actors, actions, and objects likely to be present in a given situation.” Put otherwise, a script is a “routine” (Nelson and

Winter 1982), which when combined with a tool and an actor becomes a tightly coupled system to accomplish a goal-state. By its association with a technical script, a tool gains social meaning; it becomes an *implement* for creating a particular condition or end-state.

Technical scripts are imbedded in the shared technological frames of networks of users (Bijker 1987). The technological frame provides a language of common discourse for social networks of the people who make, distribute, and use particular kinds of implements to attain goals.

Technologies (i.e., implements and technical scripts) are organized into larger technical systems and master frames. In larger behavioral systems, actors and objects are linked *thematically* and *functionally* (Fivush 1987). In some thematic systems, there is a relatively loose linkage, or coupling, between objects. For example, a farmer may have the option of using various techniques to rid a field of weeds. Other technical systems involve more tightly organized technical sequences—for example, when and how to plant a corn crop. In this case, the various objects in the chain of activities—tractor, planter, seed, field, etc.—comprise a relatively tightly linked thematic sequence.

At each step in the sequence of tillage and cropping activities, however, choices may be made among functional equivalents. For example, in planting corn, the farmer may select one among several tractors to pull the planter; he will select one among several functionally equivalent varieties of seed, and so on. A system comprised of functionally equivalent elements is loosely coupled. Significantly, farmers choose the particular objects and pattern of activities to suit their perceived needs, including the farming situation, taste, competency, aspirations, social values, and so on (Akrich 1992). In personalizing a technical system, an exemplar of an abstract system is created that bears the imprint of the master technical frame from which it is derived.

As streams of purposeful activities, technical systems have expected products or attain expected conditions, and they achieve valued goals (i.e., they are teleological). The dominant values of the system activities thus are instrumental. However, expressive and moral values also shape technical activities. In other words, although considerations of efficiency and effectiveness of activities are normally paramount, the “pleasantness” and the “goodness” of tillage activities from the farmer’s point of view in producing the desired outcomes are also important.

Three types of systems are particularly relevant to this study—the tillage system, farming system, and agrifamily system (table 2.1). The systems are hierarchical in the sense that the goals of the higher ranking systems have priority over the goals of lower ranking systems. In other words, control is exercised from the top down. Moreover, as one moves

Table 2.1. Agri-family system and subsystems.

System Level	System Type	System Integration	Goals
5	Agri-family system	Individual, family, farm, off-farm work	Lifestyle, human development, savings, and investment
4	Farming system	Cropping, livestock	Crop and livestock production
3	Tillage system	Technical frames and scripts for weed control and cropping	Landscape management, soil resource development, and conservation
2	Technical scripts	Instructions for using implements (tools)	Weed and pest control, planting, fertilizing, harvesting
1	Tools	Components	Potential uses

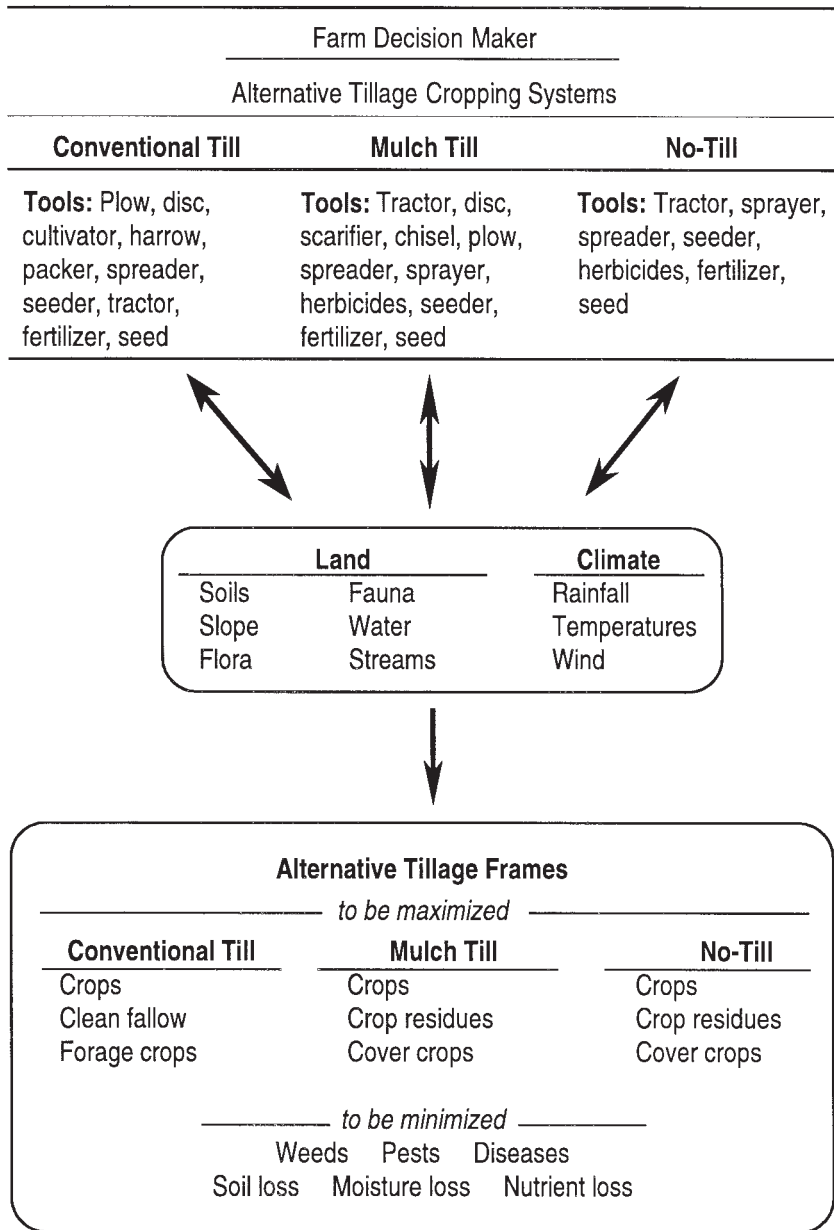
from lower to higher ranking systems, the systems become more complex in the sense of being composed of—or of integrating the goal-activities of—the lower ranking systems. In this sense, all systems are subsystems of the agrifamily system, which is the highest level of system integration under the control of an individual farm family (Bennett 1982).<sup>5</sup> The defining feature of an agrifamily system is the particular strategy for using family resources to generate income for reinvestment and a farm lifestyle.

The first proposition of this study is that *conservation tillage systems* (e.g., *mulch tillage*) are farmer-managed sociotechnical crop production systems. As a technical tillage system, each organizes thematically and functionally an array of implements and technical scripts. Particularly relevant for our purposes are (1) the *tillage master frame for specific crops* and (2) *tillage operating systems* for growing a particular crop. A tillage technical master frame consists of current *theories of tillage*, the land resource and cropping goals, *problem-solving strategies*, (e.g., for growing corn), and *technical scripts* along with the appropriate *implements*.<sup>6</sup> It is the general knowledge of a particular type of tillage system found in books, extension, and commercial company publications, and shared by various practitioners—applied scientists, extension workers, and farmers. *Tillage theory* consists of theories about soil fertility and structure, mineral, moisture, and soil particle movement, effects of plant competition, seed-soil contact, plant emergence, weed control, and the like. Such theory undergirds technical scripts for particular implements, and a “strategy” for using the latter to attain specific environmental and socioeconomic goals. Being shared by scientists, farm advisors, and practitioners, tillage master frames are cultural products.

The master tillage goal of manipulating the biophysical environment, or farm landscape, to grow a crop encompasses a variety of more specific goal(s) embodied in particular tillage frames. Because agriculture in the United States and Australia is carried out on farms operated by self-interested entrepreneurs, the environmental goals of their tillage master frames primarily serve to preserve these farming systems. As Pierce (1985, 5) puts it: "There are two essential components of crop production systems: they must be *sustainable* and they must be *profitable*." Neither of these criteria, however, is an unambiguous guide. Most systems are sustainable at some level, although one system may be more sustainable than another. Similarly, although one tillage system may be more profitable than another, several may be profitable. Suffice to say, in the first half of the twentieth century, plow culture was the dominant tillage master frame for commercial agriculture, and in some areas cropping combined with livestock production was sustained for a very long time. The main goal of plow tillage is to prepare a finely tilled plant bed, free of weeds and plant residues, and nourished by the necessary micronutrients to grow a particular crop. If the latter is a row crop, the tillage frame has the additional goal of maintaining a weed-free crop by mechanical, in-row cultivation. Implements and technical scripts are selected under the guide of profitability criteria to accomplish this goal (fig. 2.1).

The second half of the twentieth century witnessed the evolutionary innovation of several tillage master frames containing the radically different goal of developing or *constructing a fertile landscape that is permanently covered either with plant residues, cover crops, or profitable commercial crops*. These tillage frames and the operating systems derived from them are variously termed "stubble mulching," "plow plant," "minimum tillage," "mulch tillage," "ridge tillage," "zero tillage," and the like. The terms reflect the different proximate goals of each tillage frame (e.g., leaving crop stubble on the surface as a mulch, or no tillage of the field between harvesting a crop and planting another crop). In this book, we use the term "conservation tillage" to refer to the various tillage methods that differ from "conventional tillage." The *Resource Conservation Glossary* (Mannering and Fenster 1983, 141) defines "conservation tillage" as "any tillage system that reduces loss of soil or water relative to conventional tillage; often a form of noninversion tillage that retains protective amounts of residue mulch on the surface."<sup>7</sup> The saving of soil and water, of course, is the principal environmental goal obtained through maintaining a permanently covered farm landscape by use of the new tillage methods. Conventional tillage (plow tillage), on the other hand, used primary and secondary tillage operations to prepare a clean, finely tilled seed bed for grain crops. Such seed beds are vulnerable to rapid evaporation of soil moisture and severe erosion.

Figure 2.1. Model of alternative tillage cropping systems.





Conservation tillage frames (as well as plow culture) differ as to the management *strategy* of weed control and plant bed preparation. Although the strategy of mulch tillage is to use minimally invasive cultivation and herbicides to control weeds and prepare for planting a crop with a trash planter, a zero-tillage strategy accomplishes these aims by use of herbicides alone and a zero-till planter. Different tillage strategies are necessitated by the range in socioenvironmental conditions confronting farmers.

Although the goal of a permanently covered landscape is best achieved with zero tillage, use of this tillage frame may be unsuitable for various reasons. The effects of national policies and the prices of inputs may make particular tillage implements relatively expensive. The local climate, soils, or the crop a farmer plans to grow may be unsuited to a particular tillage system. The farmer may not know how to use particular tillage techniques (e.g., herbicides). Put otherwise, to attain desired ends a tillage system strategy is adaptive with respect to a range of environmental and socioeconomic conditions of a particular farmer.<sup>8</sup>

A tillage operating system is derived from a tillage master frame and contains solutions to the particular problems faced by an individual farmer in a specific location in growing crops on his farm. Where the tillage master frame is general, the operating system is the farmer's specific guide to dealing with everyday life problems on his farm. It incorporates a particular farmer's abilities and capital goods along with the realities of the soils, plants, and climate on his farm, and the particular cropping goals that the tillage system must accomplish. For a grain farmer, the tillage and cropping system are the principal components of his farming system.

For purposes of investigating changes in a farmer's tillage system(s), the farming system is the most relevant, general frame of reference. The goals and management strategy of the farming system determine the goals of the tillage and cropping systems as well as the resources allocated for their operations.

### *Farm Landscape and Local Networks as Symbolic Frames*

Because of their economic goals, tillage systems along with other subsystems of farming systems have an instrumental bent under a utilitarian system of values (Bennett 1969, 1982; Parsons 1952). In this respect, techniques and tillage systems typically are primarily evaluated in terms of efficiency and effectiveness in attaining prescribed goals. But, economic goals are not the only goals of farming, often not even the most important ones. For the German yeoman farmers studied by Salamon (1992, 101) profits are merely the means to the paramount aim of main-

taining the “family name in conjunction with a particular farm in a German community.” This gives farmland a sacred meaning sharply different from the unsentimental view of land as a business asset by Yankee entrepreneurs.<sup>9</sup> Walter (1997) found that Illinois farmers differed in their definitions of a successful farmer. For some, a successful farmer was a good “steward,” whereas for others it was having an agrarian lifestyle, and for still others it meant being a successful manager. Farmers derive satisfaction from farm work because of its noneconomic as well as its economic rewards (Coughenour and Swanson 1988).

The diversity of farming goals and rewards occurs in part because the constraints exercised by environmental and institutional forces on farming systems are sufficiently indeterminate that various farming strategies can achieve “satisficing” economic as well as lifestyle goals. Moreover, agrifamily systems for which agrarian lifestyle goals dominate, for example, exist because agrarian institutions mandate that farms be organized by entrepreneurs. An entrepreneur establishes an agrifamily system that reflects his (family) interests and “self-image.”<sup>10</sup>

We refer to the meaningful (cognitive) natural environment, which a farmer constructs, as a *symbolic landscape* (Greider and Garkovich 1994). That is, the farmer views the biophysical environment of his farm through a symbolic lens of his own construction. Similarly, the persons and groups with whom the farmer interacts to provide the necessary goods and services for his tillage and cropping activities constitute a *symbolic social network*. Put otherwise, through his activities vis-à-vis the natural and social environments, the farmer constructs natural and social worlds that have meaning for him.

Because these symbolic worlds are our own constructions, we find ourselves mirrored in them. As Greider and Garkovich (1994, 2) put it, through the use of sociocultural symbols, “the physical environment is transformed into landscapes that are the reflections of how we define ourselves.” This identity, which is projected into the created symbolic environment, is foremost a “collective identity” (Gamson 1992). It denotes the type of person we are culturally. In particular, the way a farmer defines himself, for example, as a “manager” or a “steward,” has implications for the symbolic landscape he creates and the real landscape he seeks to develop (Berry 1977). Where the one views the soil and plants primarily through the prism of costs and benefits as commodities, the other sees possibilities of conservation, preservation, or enhancement.

But also, the farmer’s landscape necessarily reflects the way in which he symbolizes the environmental reality out there—the variety of socioeconomic resources and constraints (Bennett 1982; Coughenour 1984).

The overriding purpose of a tillage system is to improve the biophysical landscape as a resource and reduce the constraints for the production of specific crops. Conventional and conservation tillage systems differ in the inclusiveness of the biological systems viewed as resources. For some farmers, the resource map tends to be limited to the land and the “crop;” all else are competitors. This defines a landscape that is a battleground in which the farmer is engaged in defensive warfare to control all other “noneconomic” plants, insects, and animals. Alternatively, the economic “crop” is seen in competitive, symbiotic, and communalistic relationships with other biota. This view of the landscape orients the farmer to the complex soil-plant relationships, which he seeks to manage and maintain satisfactory control (Altieri 1987; Duffy 1998). Moreover, the broadening of the farmer’s interests come to include not only the *crop* and its soil base but also water quality and other related biota.

One’s sociocultural “identity” and socioenvironmental “consciousness” are contested cultural terrain in all social movements (Gamson 1992). The farmer’s identity as steward of his farmland, his consciousness of the agroecological environment, and the “exploitive” versus “conservation” bent of his farming activities have been major battlegrounds since World War II and especially since the environmental movement began (Berry 1977; Buttel 1975; Napier and Forster 1982; Jackson et al. 1984; Beus and Dunlap 1990; Reeve 1992; McCloskey 1992). In the process of cultural change, for example, older labels of farmers as yeomen or agribusinessmen have been eclipsed by whether farmers adhere to “conventional” or “alternative” agricultural paradigms. A change in social consciousness and collective identity sets the stage for transformation of the tillage system itself as appropriate techniques become available. For example, Beus and Dunlap (1994) and Allen and Bernhardt (1995) have shown that a farmer’s adherence to a conventional versus alternative paradigm matters in terms of his practice of farming.

We use the concept of *symbolic social network* to refer to a farmer’s conceptual map of the societal “resources” (i.e., input suppliers, agency representatives, and other farmers) supporting or sustaining his tillage system. It defines the relevant social space, or social landscape. With the master tillage frame as the guide, this symbolic social network is socially constructed by the farmer in social interaction with other farmers and agents. In this sense, a farmer’s symbolic social network converges with the networks of neighboring farmers. Together they sustain a common tillage culture.

Collectively, the shared representations delineate a local society and culture providing guidance and support to members’ farming activities.

A farmer's symbolic network both contributes to, and supports, the farmer's self-image, as well as the kind of landscape he constructs. That is, there is a reflexive relationship between farmers consciousness and social structure (Stryker and Statham 1985). The process of social construction is reflexive because the farmer's identity and mandate as a farmer are derived from the community in which he lives and its agricultural institutions (Bennett 1969; Salamon 1992).

Although local agrarian institutions form a broad framework for agriculture, they do not supply the specific details. Agrarian institutions "mandate" that the farmer qua farmer entrepreneur design and develop his own farming system, including the details of his own role. The autonomy, which this provides, enables the farmer to shape the socioeconomic environment according to his view of himself as a farmer including his specific farm enterprise interests and preferences (Bennett 1982; Coughenour 1980). Using images and contacts with the media, governmental farm agencies, businesses, and farmers, the farmer constructs a symbolic social network for his tillage system. The symbolic social network has a utilitarian bent, as does his symbolic landscape.

A mandate to serve farm people underpins all agricultural institutions and legitimizes the establishment of agency-clientele networks. That is, the formation of such networks is both legitimate and mutually beneficial. Both the *real* and the *symbolic* social networks become part of everyday life of a person growing up in a farming community. A real social network may be problematic when a person begins farming or moves to a new community, or when there is change in agricultural institutions. Both the real and the symbolic social network become problematic with the creation of a new (revolutionary) technical culture. It is our contention that this has been the case with the innovation of conservation tillage systems. Thus, the reconstruction of farmers' symbolic and real social networks is an important aspect of the process of creating a new tillage system and its technical scripts.

In summary, a tillage system consists (1) of a symbolic master frame containing implements, technical scripts, and a strategy for using them to construct a symbolic landscape and attain cropping goals. (2) The master frame is a component of local culture shared by a local network of farmers, professional advisors, and agency representatives. (3) New tillage frames entail the reconstruction of both the symbolic landscape and symbolic social network. The theory of the development of the local network and its new culture of conservation tillage and cropping is presented in the following section.

## Social Construction of Systems: Structure and Process

An innovation is commonly defined as any “idea, practice, or object that is perceived as new” (Rogers 1983, 11), and conservation tillage systems are perceived as new. Many, indeed most, new techniques are important because they increase the efficiency or effectiveness of accomplishing some particular goal. For example, the jet engine made faster flight possible; it sparked a great expansion in human flight, but the system goal of air transport remained the same. Similarly, 2,4-D weedicide was an innovation in weed control, but the conventional system of cropping was changed little by this innovation.<sup>11</sup>

Conservation tillage systems, however, are innovations in a more important sense. Conservation tillage systems are innovations in the special sense of new tillage system paradigms based on new knowledge of the biophysical environment, different management strategies, and new landscape goals and identity as a farmer. It is a new paradigm innovation (Barnett 1953; Nisbet 1969). As such, conservation cropping is a radically different system for the management of fallow and the planting and raising of agricultural crops. Secondly, being shared by farmers, change agents, agricultural scientists and others, the conservation (tillage) cropping frame constitutes a new culture of agriculture—new local knowledge, technique, and social relationships for the practice of agriculture (Warren 1991; Rhoades 1989; Maurya 1989).

As we indicate in chapter 4, several components of the new tillage master frames initially were innovations developed ostensibly to improve the effectiveness of conventional (plow) agriculture. The innovation of conservation tillage, however, began with “notions”<sup>12</sup> of a new tillage frame and systems developed primarily by agricultural scientists (McCalla and Army 1960; van Es and Notier 1988). The initial experiments by agricultural scientists demonstrated that a crop could be grown successfully with no-tillage. However, as chapter 5 reveals, much of the work of elaborating the new master frame as well as the construction of successful operating systems (i.e., of modifying implements, constructing technical scripts, and developing the critically important operational strategies) was accomplished by networks of farmers and farm advisors.

Callon’s (1987, 93) concept of an *actor network* as “simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of” is useful in this case. A farmer as actor, for example, is continually networking (interacting) with others to put together the necessary elements (e.g., information, machines, chemicals, seeds, etc.) to plant and grow a crop.

At the same time, the farmer—together with other farmers, scientists, agents, advisors, sales persons, and the like with whom the farmer interacts—are continually modifying the elements (i.e., changing the technical frame). Constant (1987) refers to this large complex of practitioners, technology producers, and scientists/laboratories as an overall technological system. The actor network thus has a dual meaning. It consists of a loosely coupled system of human actors and an equally loosely linked set of techniques, theories, and practices. An innovative network is continually engaged in modifying both aspects.

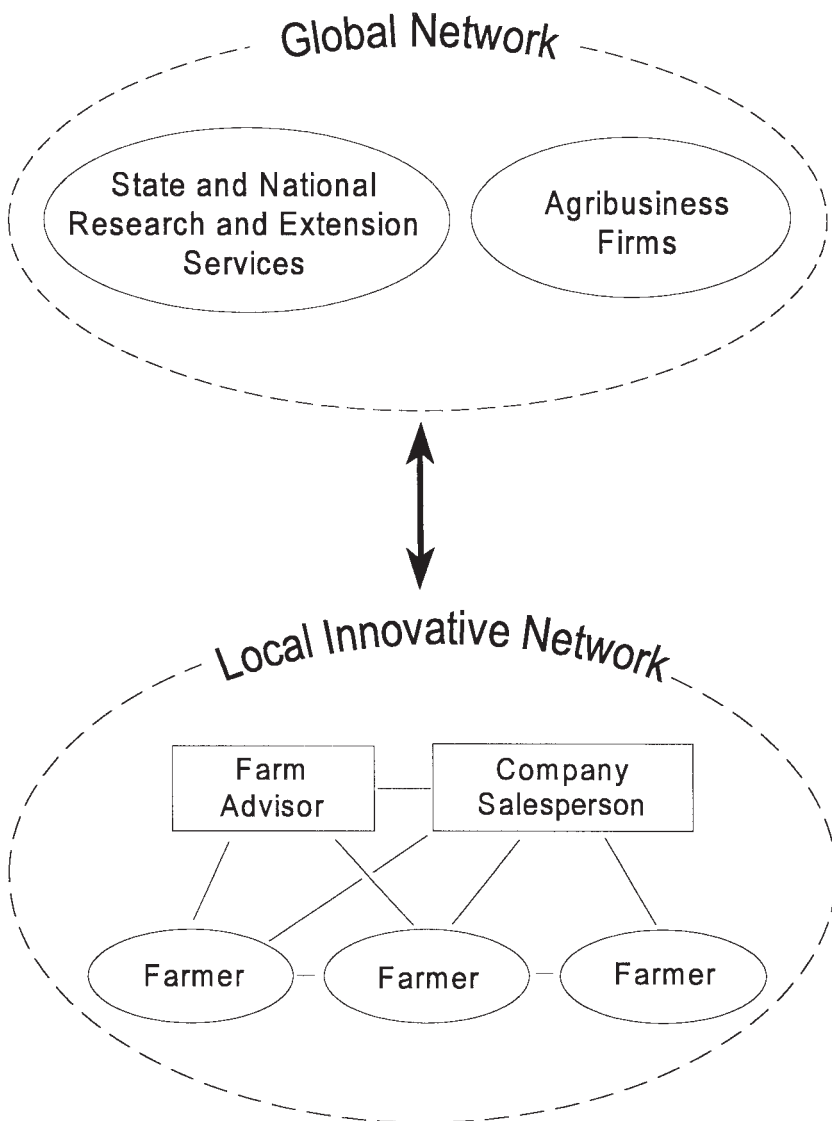
In focusing on the farmer as the key network actor in the case of conservation tillage systems, we contend not only that he has fate-control of the assembled technologies but also that only he can effectively construct a successful tillage cropping system for his farm.<sup>13</sup> A farmer, and no one else, has a tillage cropping system on his farm. It is nonetheless evident that in constructing a successful no-tillage system, no one farmer, regardless of his innovativeness, nor several of them and their local advisors together were able to construct the first successful no-tillage cropping systems. As indicated in chapters 5, 6, and 7, they made use of all the available information and resources they could command nationally in constructing the new systems. Law and Callon's (1992) conceptualization of a "local" innovative network developing linkages with a "global" network in order to obtain the necessary resources to construct a successful system helps clarify this situation.

The second proposition guiding this study is that *conservation tillage operating systems are innovative social constructions of farmers and professional farm advisors in local social networks linked to global networks* (fig. 2.2).

This proposition has two important theoretical implications. First, the process of innovation of tillage systems qua systems is qualitatively different from that of an ordinary technical innovation that is developed by an industrial company and marketed to farmer users. The tillage systems were what the farmers developed.

Second, the process by which tillage systems spread geographically is fundamentally a process of developing new innovative local networks and thus is qualitatively different from the typical process of the diffusion of technical innovations (Rogers 1983). In the establishment of local innovative networks, institutional agents (Barnett 1953), rather than media, play the most prominent role. The third proposition guiding the analysis thus is that *innovative tillage systems are spread by institutional ("change") agents who initiate formation of new local innovative networks*. Institutional advocates of the new tillage frame (i.e., extension and soil conservation agents in the United States and soil conservation agents in Australia) took the locally constructed tillage frame and

Figure 2.2. Global and local innovative networks.



established new networks of farmers in other areas who “reinvented” (Rogers 1983) no-tillage systems. The key role of institutional advocates in spreading new tillage system frames, we argue, is prototypical of the diffusion of *systems* that are managed by human agents, by contrast to the diffusion of *implements* that are operated by human agents with technical scripts.

In emphasizing the key role in diffusion of institutional advocates of the new tillage culture, we do not overlook the importance of scientific research on conservation tillage. During the decades following the local construction of no-tillage, agricultural scientists greatly increased scientific understanding of no-tillage agriculture. Expanded scientific knowledge of conservation tillage substantially helped overcome early difficulties with the new systems, enabling initial users to expand the use of conservation tillage systems, and facilitated the spread of conservation tillage systems to new areas.

### *Initiating Change in a Local Innovative Network*

Identification of a “notional” technical frame, which ostensibly provides better solutions to a critical problem in the symbolic landscape, not only threatens the adequacy of the existing technical frame, it also casts doubt on the adequacy of the supporting “local networks” (Law and Callon 1992; Bijker 1987). This problematic condition sets in motion search processes for sources of more satisfactory information and resource support. Notions of a different technical frame become salient. The process is iterative rather than linear. That is, while attending to the new technical frame, the farmer builds trust-based relationships with new “sources” of information, and this leads to further elaboration of the technical frame and a different tillage system, which provides incentives to stronger relationships with the new sources, and so on.

As Bijker (1987) emphasizes, the new “technical frame” is elaborated until it incorporates the necessary supporting individuals and groups. Farmers’ conservation tillage (technical) frames, for example, were progressively broadened to include chemical and different machinery company representatives, government soil conservation agents, experts on residue management, soils, crops, and economics, as well as other farmers with varied cropping systems and farm landscapes. The search for the necessary support compels members of the local network to seek the support of individuals and agencies in the “global” arena. With respect to conservation cropping, the global network is the social space within which a local network “negotiates” commitments necessary for the construction of workable tillage systems. Development of the larger network goes hand in hand with frame and script development (Law and Callon 1992).



This process of reconstructing social space develops in three phases. The first is the identification of persons, either farmers or farm advisors (depending on which party initiates the networking process), who recognize that a problem with the conventional system exists and who have an interest in a different notional tillage system. Shared interests of the person(s) in the new frame is the key starting point.<sup>14</sup> Second, both the level of interest—"stake"—and nature of the interest in a favorable development outcome must be determined through interaction and negotiation. Evidence of general interest in some aspect of conservation tillage, for example, is not sufficient.

The level of a specific interest in developing a suitable tillage system and, thus, of co-investing time and effort in the process is the critical issue in building an innovative local network. For example, although some stakeholders may be interested in using herbicides, others may be interested in supplying both information and product, and still others may be interested in the use of trash planters, and so on. All are necessary in obtaining a successful outcome.

Third, there is the acquisition of diffuse information about the authenticity, dependability, and cooperativeness of each source. Trust is the system attitude that develops among stakeholders as the three phases progress (Gambetta 1988). As it develops, trust facilitates the organization of the stakeholders in a system of mutual, complementary, and competitive interests. Whereas farmers have mutual interests as farmers, their interests are complementary to the interests of agricultural agency and business representatives. At the same time, agency and business agents have competitive and complementary relationships with each other. In other words, all network participants—farmers, agency, and business representatives—increasingly recognize that their common fate depends on their success in elaborating an operational technical frame and in providing the essential resources. Recognition of common fate motivates establishment of social commitments to the local network (Kanter 1968; Stryker and Statham 1985). As a new system of mutually expected behavior develops and is refined, both the old social space and the old tillage culture tend to wither.

Because the network commitments, undergirding the new social space, are based on a new technical frame, the relationships impact the farmer's role-identity. Consequently, a shift in commitments to a new socioeconomic network erodes the old role-identity and bolsters creation of a new one. The greater the substantive change in the cultural basis of the local network, the greater the change in the farmer's role-identity. Successful operation of the new tillage system confirms the farmer's new identity, thereby providing the motivational basis for the

continued “evolution” of the new technical frame and tillage system and its utilization.

Earlier we noted that any crop production system, including its tillage system, must satisfy two criteria: it must be *sustainable* and *profitable* (Pierce 1985). Both system criteria obey the “satisficing” rule. That is, in terms of the ordinary standards of the local farming community, his tillage system must be satisfactorily sustainable and profitable as he perceives it. The fourth proposition guiding this study is that *a change in a tillage master frame and local network is initiated when a farmer experiences unresolved dissonance, or dissatisfying imbalance, in his goal state(s) from operation of his tillage system, resulting in repetitive cycles of action-learning*.<sup>15</sup>

Dissonance has been defined as a logical inconsistency of related objects or categories (Festinger 1957), and more subjectively as disharmony among the meanings of related conceptual categories (Bell 1994). That is, dissonance is created by a salient stimulus condition that arrests attention and arouses memory and interpretive processes.<sup>16</sup> Festinger (1957) argued that dissonance aroused a drive analogous to hunger, and a dissonant state is now recognized as a general motivator of change because it engages the “self” in various ways (Markus and Zajonc 1985). In the present case, dissonance derived from with failure of the tillage system to attain profitable or sustainable goals motivates the farmer to act because it threatens his identity as a “successful” farmer.

In particular, a dissonant state may occur if the farmer perceives that weeds he failed to kill last year have multiplied and will be more costly to control. Often, the farmer can remove this imbalance by a minor adjustment in tillage technique, (e.g., spraying the weedy area). In this case, no fundamental change in the symbolic landscape or the base paradigm of the existing tillage frame has occurred.

However, when such adaptive responses do not suffice to restore harmony in the symbolic landscape, the motivation for further, more fundamental change is elicited. Such a dissonant condition may arise when strongly negative outcomes occur, or are likely to occur, from conventional strategy and practice.<sup>17</sup> We will be primarily interested in three sources of motivation for systemic change. First, dissonance leading to systemic change may occur if the farmer (1) perceives potentially severe destruction of the biophysical field (e.g., a progressive loss of soil resources); (2) he believes this is due to existing tillage practices; and (3) this is inconsistent with his symbolic landscape as a resource for cropping. Second, dissonance eliciting systemic change may occur when information about a new set of implements and technical scripts, (e.g., herbicides) offers the prospect of reduced tillage costs and/or opportunity for expansion of profitable cropping operations. Continuation of

conventional tillage is inconsistent with the goal of minimizing costs and increasing profits.

Finally, the farmer may experience dissonance because he has assimilated a new collective identity as conservationist and a new consciousness of a sustainable farm landscape that are incompatible with the symbolic and real landscape created by conventional tillage.<sup>18</sup> A state of dissonance associated with conventional tillage motivates social construction of a new tillage and cropping frame.

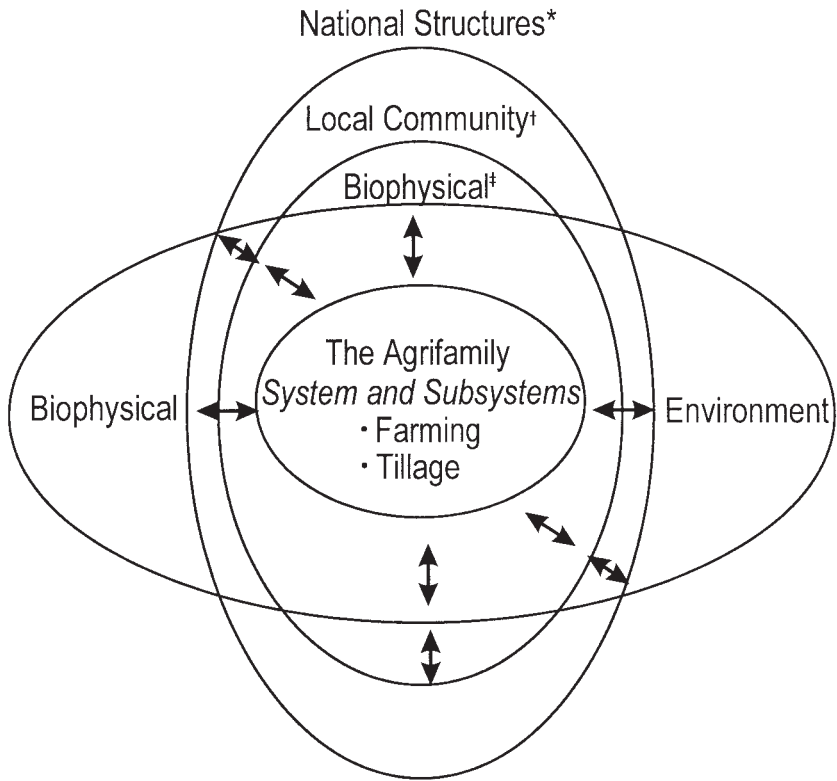
Following Bennett (1982), we conceive of the entrepreneurial farmer making decisions in an “adaptive nexus” or situational field of forces. The field is composed of three categories of constraints to the attainment of agrifamily system goals: biophysical (environmental) phenomena, microsocial (local community) phenomena, and macrosocial phenomena (national institutions, markets, governmental policies, and social movements) (fig. 2.3). The function of technological systems, including the supporting local and global networks, is to convert constraining forces into resources, thereby providing a positive balance in the nexus of forces. This creates opportunities for the farmer to attain system goals.<sup>19</sup>

Changes in the nexus of forces can result in technological failure and the arousal of dissonance-motivated adaptive behavior. Technological innovation is one result of adaptive effort. In specific terms, we aim to show in chapter 4 how changes in national conservation and commodity policies destabilized the adaptive nexus of farm operators, thereby creating dissonance and motivation to develop innovative conservation tillage systems. The innovative technological systems enabled farmers to better attain farming system goals.

### *Restoring Harmony in the Tillage Frame: The Action-Learning Cycle*

Dissonance threatening sustainable or profitable goals not only implicates the effectiveness of existing techniques, but also the technical frame itself. When this happens, finding a satisfactory solution to the problem becomes difficult. That is, simple problem solving using theories underpinning the existing tillage frame proves impossible.<sup>20</sup> For example, in the 1950s, Queensland farmers burned wheat fields after harvest to facilitate plowing with a moldboard plow, but they began to recognize that after the stubble was removed, the ground quickly became very hard and was easily eroded. Both conditions were inconsistent with the goal of maintaining or improving soil resources; with the progressive loss of soil, the motivation to change increased. But, the problem was not as simple as stopping burning because this would substantially increase the costs of plowing. Initially, the situation was re-

Figure 2.3. The situational nexus of the agrifamily system.



\*Policies, regulations, social movements, agencies, agribusinesses

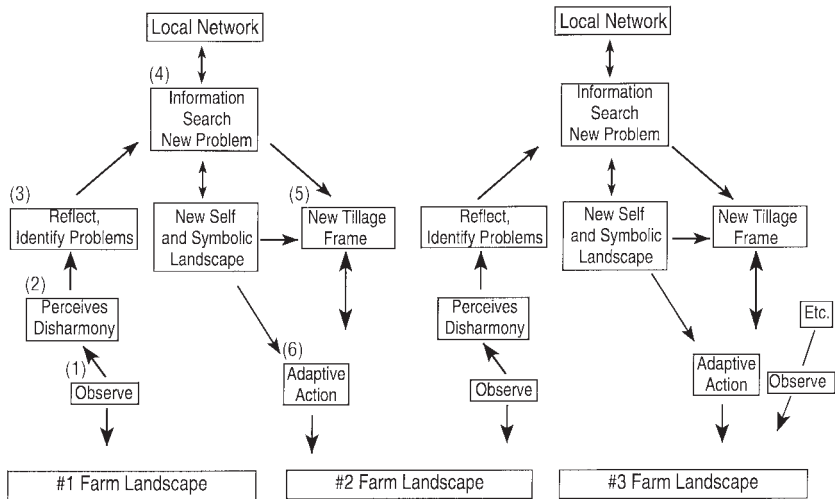
†Other farmers, advisors, agencies' representatives

‡Weeds, soils, topography, climate

defined as a problem of designing a plow that could operate with stubble, and disc plows were obtained. However, soil erosion remained a problem, and the new problem was how to plow and retain crop residues. This led to the adoption of tined plows and cultivators. But, this entailed adopting a new symbolic landscape as well as new social networks for the testing, evaluation, and development of new cultivation and planting machines and technical scripts.

A model illustrating dissonance reduction through the process of action-learning of new frames is shown in figure 2.4.<sup>21</sup> In stepwise fashion, (1) observation of the farm landscape produced by conventional practice results (2) in perceived disharmony with the farmer's symbolic

Figure 2.4. Model of action-learning sequence: constructing new tillage frame, landscape, and social identity.



landscape. (3) Motivated reflection leads to definition of the problem based on a “notion” of a new tillage frame. The “notional” frame, however, must be “developed” into practical goals, techniques, and operational strategy. This requires (4) the social construction of a network of informational advisors and resource providers, as was discussed earlier.

The next step (5) is construction of a “preliminary” tillage frame, including a new symbolic landscape, tillage techniques, and a “trial” operating system. The result (6) is a new landscape and cropping products. If, as typically occurs, observation of the new landscape and evaluation of the sustainability and profitability of the outcomes result in perceived disharmony, the farmer and his network are activated once again to further modify the new tillage system.

The development and testing of alternative techniques are iterative processes. Each cropping season provides a new opportunity to test new strategies or techniques. Often, several farmers are developing and testing various alternative techniques simultaneously. Eventually, new technical script(s) produce trial outcomes that are “satisficing” (Abelson and Levi 1985; Simon 1972). This enables a farmer to commit the human and financial resources necessary to make the new technical script an operative component of a revised tillage system strategy. In other words, the farmer has a revised/new tillage strategy, which either partially or completely replaces the old technical scripts. Enactment of the new

tillage system produces a new, more harmonious symbolic landscape and cropping outcome.

The stronger the dissonance associated with the symbolic landscape or cropping outcomes, the greater the farmer's motivation to search for information about a qualitatively different tillage frame (i.e., goals and techniques). Such information almost invariably has different advocates ("sources").<sup>22</sup> Although information from the new network sources leads to action-learning of new technical scripts, it also leads to the "transformation" of the farmer's symbolic frames (Snow et al. 1986). For example, recognition that bare ground left the soil vulnerable to erosion, despite incorporation of stubble, eventually persuaded farmers to shift from clean ground as the tillage goal to a goal of weed-free, but continuously covered and protected, ground.

The emergence of this new landscape goal results in a devaluation of conventional techniques and in innovation of alternative tillage systems with (1) a differently valued landscape, (2) new land and water resource and cropping goals, (3) a new master frame with new implements, technical scripts, and strategy for attaining different cropping goals, and (4) a new identity as a farmer. The widespread acceptance of this new set of beliefs of a more sustainable cropping system, which is shared by legions of farmers and their supporting networks, is *the hallmark of a cultural revolution in cropping agriculture, including a new social identity of farmers.*

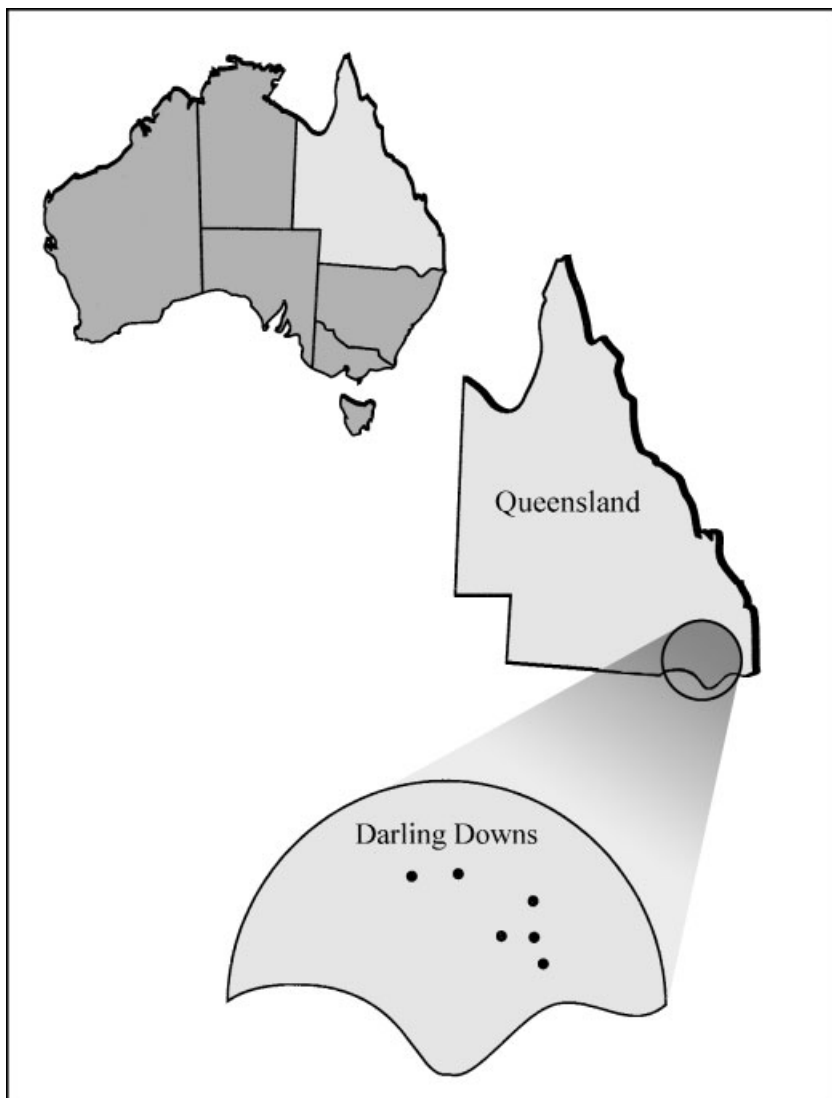
As we show in chapter 9, these new tillage systems have become widely accepted in forty-six of the fifty states and Puerto Rico. Early in this new millennium, more than one-half of the cropland will be managed under conservation tillage systems of cropping. In this respect, the alternative tillage systems have become conventional, even though many adaptive problems still remain unresolved.

### The Study of Conservation Cropping in the United States and Australia

The study was initiated in 1988 with in-depth interviews of six farmers on the Darling Downs in Queensland, Australia (fig. 2.5). The aim of each interview was to chronicle the event-experiences of each innovator in his movement from conventional tillage to the present system of conservation tillage. The interviews generally ranged over the preceding two decades. The general format of the interviews was:

- present farm operation and history of property acquisition.
- tillage practices when began farming and initial interest in soil conservation.

Figure 2.5. Conservation tillage innovators in Queensland.



- significant event(s) causing initial change in tillage.
- information and information source(s).
- goals and experiences with new tillage practices.
- subsequent events leading to further change in tillage.
- difficulties encountered with new tillage system.
- revised goals, experimentation, and development of knowledge.
- current situation, practices, problems, and attitudes as to future practice of conservation tillage.

In-depth interviews also were conducted with administrators and field officers of the Soil Conservation Branch and the Agricultural Branch of the Department of Primary Industries, Queensland, who had been involved in the conservation tillage research and extension programs. These interviews were followed up in 1995 with additional interviews to record the innovators' experiences with conservation tillage since 1988 and their current tillage practices. Interview materials have been supplemented when possible with written documents by the innovators of their conservation tillage experiences.

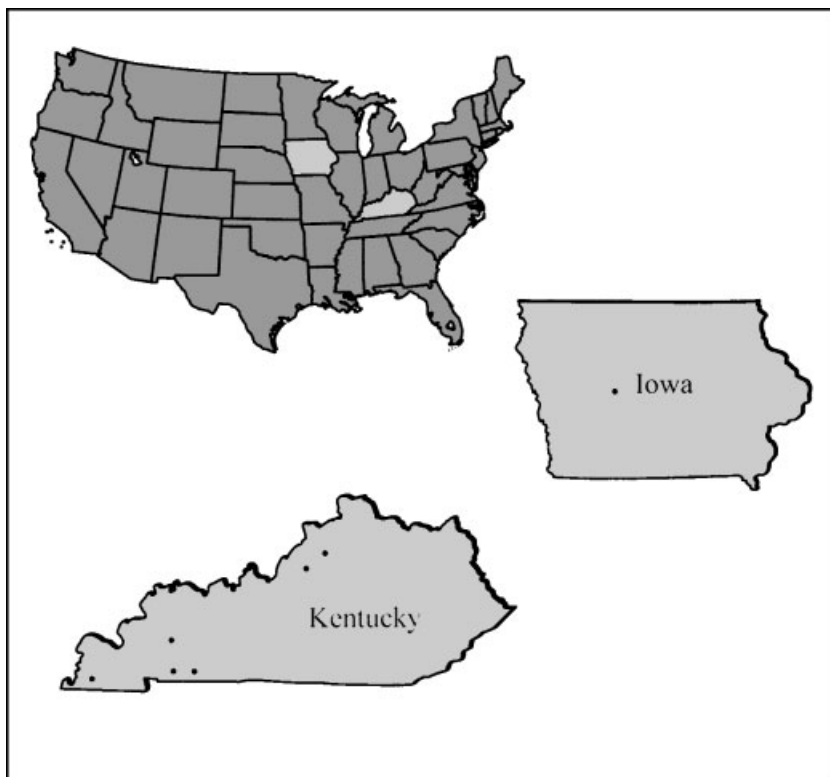
Sales representatives of ICI, Ltd., Monsanto, and Conner-Shea Napiers were interviewed in 1988 concerning their experimental and other efforts to provide suitable chemical herbicides and machinery to farmers on the Darling Downs. The interview data provide valuable data on the roles of these companies and their relationships with public institutions in the support of conservation tillage systems.

No-tillage cropping originated in Christian County in southwest Kentucky and spread from there to other counties and states (Phillips and Young 1973; Choi 1981; van Es and Notier 1988). As indicated in chapter 8, Kentucky quickly became one of the leading states in no-tillage cropping and has continued to lead in the proportion of grain crops under no-tillage. Christian County is one of the largest Kentucky counties in geographic area. Topographically, the county is divided between a gently rolling, fertile plain in the South and a more broken, hilly, and less fertile northern section. Temperature and rainfall are favorable to crops, and agriculture is important in the county and surrounding area.

For comparative purposes, the authors conducted in-depth interviews in 1992 with five innovators of no-tillage located in southwest and central Kentucky (fig. 2.6). In addition, the story of Harry Young, Jr.'s innovation of no-tillage is compiled from published sources and interview data from John Young, Reeves Davie, and Shirley Phillips. The objective and format of the interview was the same as that used in Australia. The interviews generally covered farmers' experiences with no-till cropping from the late 1960s to the present. Interviews also were



Figure 2.6. Conservation tillage innovators in Kentucky and Iowa.



conducted with University of Kentucky research and extension workers who had been involved in early work with no-tillage, including several county extension agents. Due to the novelty of no-tillage, farmer experiences with the system often were reported in farm magazines, such as *The Progressive Farmer*, and these articles provided valuable supplementary documentation. The story of Ernest Behn's construction of ridge tillage in Iowa was compiled from published sources.

The authors also have had the opportunity to use part of a taped interview by Joe Williams' with Reeves Davie, former County Agricultural Agent of Christian County, concerning his work in the development and promotion of no-tillage cropping in the 1960s. Notable in this regard is Davie's relationships with Harry Young, Jr., Shirley Phillips, and other professional research and extension workers.

The principal source of secondary data on the spread of conservation tillage systems has been the annual surveys of tillage practices reported by *No-Till Farmer*. The Conservation Technology Information Center supplied tillage data for 1998.

## Notes

1. The term is used by Greider and Garkovich (1994) to refer to land as a sociocultural entity (i.e., in terms of its associated social, economic, esthetic, etc. meanings), and "landscape" is used in this study to denote this broad interpretation of the meaning of land.

2. We accept a constructivist approach in this study (Guba and Lincoln 1994). That is, we assume that the form and nature of reality (ontology) are relative to a locally constructed reality. The epistemological relationship between the would-be knower and the known is transactional and subjective. As Guba and Lincoln (1994, 111) put it, "The investigator and the object of investigation are assumed to be interactively linked so that the 'findings' are *literally created* [italics original] as the investigation proceeds." The methodology of eliciting and refining human, social constructions is hermeneutic techniques and interaction between the investigator(s) and respondent(s).

3. Farming and tillage systems as used herein are "soft" ("loosely coupled"), rather than "hard" ("tightly coupled"), systems (Bawden 1995; Aldrich 1979) in the sense that they are "patterns" of human activities.

4. The distinction between technique (e.g., the herbicide Roundup) and operational system (i.e., tillage system) is primarily a difference in system level and type (Boulding 1968; Hall and Fagan 1968) because both are human systems. Whereas at the technical level of analysis, there tends to be a singular object, purpose, and a relatively simple feedback loop characteristic of a relatively tightly coupled sociotechnical system, at the level of the agrosystem there are multiple objects, related purposes, and more complex monitoring, feedback, and control relationships characteristic of a loosely coupled system. Although a farmer's tillage cropping system is the primary focus of analysis here, it is itself a component of a more encompassing conceptual system (i.e., the farming system). The concept of heirarchy of control and information flow is an important attribute of the systems analysis.

5. The term "agrifamily system" was coined by Bennett (1982) to include the farm, family, and its socioenvironmental context. The idealized model depicted in figure 2.1 is in the tradition of the farming systems research of Norman et al. (1982), Hildebrand (1986), and Shaner et al. (1982).

6. The definition of "technical frame" is consistent with Bijker (1987, 171). In Kuhnian terms, a technical frame is a technical paradigm (Kuhn 1970).

7. The *Glossary of Terms Used in Soil Conservation* of the Soil Conservation Service of N.S.W. defines "conservation tillage" as "a tillage system for growing a crop and that conserves soil, water and energy resources. The essential elements

of such a system are reduction in the intensity of tillage, and retention of plant residues" (Houghton and Charman 1986, 30).

8. In the literature on the social construction of technology, the employment of different tillage strategies and techniques to accomplish the same end(s) represents a "stylistic" difference in system technology (Hughes 1987).

9. Salamon (1992) speculates that the German yeomen will be more receptive than the Yankee entrepreneurs to "sustainable" farming practices.

10. In that a farming system is a human construction serving esthetic and craftlike as well as purely economic ends, a farmer's problem-solving rationality is not only "bounded" (Simon 1972) but also substantive (Weber 1978; Mooney 1988). Only when accounting rules are used, as they often are in determining profit and loss, is formal rationality paramount.

11. Of course, the invention of 2,4-D triggered the invention of a wide range of chemical herbicides, which in combination with other innovations, became part of innovative conservation tillage systems (Peterson 1967).

12. The "notional" stage is the first stage of development of an innovation, according to Anderson and Hardaker (1979) and is followed by the "preliminary" and "developed" stages. Van Es and Notier (1988) use this framework in analyzing the development of no-tillage in the United States.

13. Cowan (1987) takes a similar position in arguing for a focus on the consumer as the key network actor in understanding the history of technology.

14. The underlying theory is of a rational actor developing a trusting attitude toward other actors in the network. It is further assumed that the actor is motivated and comprehends messages. These assumptions underlie theories of attitude change, which posit that attitude change occurs through an actor's "careful consideration and elaboration of message arguments" (Tesser and Shaffer 1990, 504). The proposition argues that attitude changes occur as a result of accepting new beliefs (Fishbein and Ajzen 1975). For extended discussion of attitudinal change theories, see Eagly and Chaiken (1993).

15. For our purpose, a sharp distinction between balance and dissonant cognitive conditions is not necessary because the resulting motivational and cognitive processes and the implications for change in attitudes and beliefs are similar. See Eagly and Chaiken (1993), chapter 10.

16. The arousal of dissonance is a function of cognitive processes—attention, memory, and inference. Salience or vividness of stimuli gain the perceiver's attention and initiate information processing. Through associative links encompassed by the technical frame, encoded information in memory is brought together for the development of cognitive inferences (e.g., inconsistency or imbalance). On cognitive processes, see Howard (1995) or Fiske and Taylor (1991).

17. Situations that impel people to think are discussed by Langer (1989).

18. Gamson (1992) discusses the importance of changes in collective identity and in consciousness as outcomes of social movements, and Klandermans (1992) discusses processes by which collective identities and consciousness are changed during social movements. Hassenein and Kloppenburg (1995) apply

social movement theory to analyze changes in farming systems due to the sustainable agriculture movement.

19. This perspective of the function of technological systems is consistent with Law (1987) and Law and Callon (1992).

20. See studies of “ill-defined” problems (Abelson and Levy 1985).

21. The model is an adaptation of the action-learning process (Kolb 1984), Zuber-Skerrit’s (1990) observe-reflect-plan-act action-research cycle, and similar farming-systems-research paradigms (Rhoades 1989).

22. Successive failure of problem-solving attempts to satisfactorily resolve dissonance erodes confidence in the existing technical frame and its goals. As this occurs, the capacity of the technical frame to limit information search declines, and information relevant to alternative technical frames and goals is processed (Fiske and Taylor 1991).

# 3

## Plow Culture in the United States and Australia

*Few tasks are so difficult and time-consuming as plowing, harrowing, and cultivating the soil. The plow has long symbolized agriculture, and the plow and its power source have long determined the shape of fields and types of soil used. Indeed, most other agricultural machines or devices become economically useful as a result of advances in plows and plowing techniques because the preparation of the soil took precedence over other farm tasks.*

—J. T. Schlebecker (1975, 97)

From an evolutionary point of view, the technology of a group or society is its adaptive culture. As agricultural technology is a strategy of exploiting the environment for desired ends, it is adaptive culture. Innovation that is successful simply enables a farmer to better utilize a particular environment (Bennett 1982; Stinchcombe 1983). But, assessment of the comparative benefits of an innovation is rarely an individual decision alone. Normally, a decision as to the relative worth of an innovation is a collective process.<sup>1</sup> Consequently, whether or not an innovation's benefits are greater than those of existing practice is nearly always a contested, and therefore political, issue (Bijker 1987; Pinch and Bijker 1987). In the case with which we are concerned, the contest during the past several decades has been between innovative systems of conservation tillage and cropping and the dominant system of *plow culture*.

Although conservation tillage and cropping have enabled many Australian and American farmers to improve their adaptation to emergent socioenvironmental and sociopolitical conditions, neither the full scope of the technical frames nor the extent of system benefits was given in the beginning. During the early period of its development, therefore, there was continual cultural warfare—controversy, debate, and argument over the relative merits of plowing and systems of conservation tillage. In order to understand the magnitude of this change and its social meaning, it is necessary to fully understand plow culture and the adaptive

problems that made change desirable. To gain this perspective, we discuss the development of plow culture in the United States and Australia. Plow agriculture reached maturity in the early part of the twentieth century; changes in agriculture following World War II, however, progressively undermined its foundations. In this chapter, we discuss the development of plow culture's technical frame, its landscape goals, ethic, place in rural society, and supporting institutional networks. The changing context of agriculture that progressively weakened the hold of plow culture on farming in Australia and the United States is discussed in chapter 4.

### Technical Frame of Plow Tillage Culture

The instruments and scripts for plowing, crucial though they are, open only a window on plow culture.<sup>2</sup> Plow culture, which was the principal resource strategy of most commercial farming communities in the United States and Australia as the twentieth century unfolded, had developed as an adaptive response to the emerging environmental and economic conditions of the previous century. In America, plow culture replaced the "garden farm culture" of subsistence farming prevalent during the first two centuries of settlement.

Prior to the nineteenth century, in areas where a grain-livestock, subsistence farming system prevailed, the primary aim of "plowing" was to provide a seedbed for corn every other year (Schlebecker 1975). Stirring the friable, forest soils with a bar-share or shovel plow accomplished this task with relative ease. Normally, wheat or barley would be broadcast either in the standing corn crop, or next spring in the corn stubble. This rotation supplied the food necessary for both the farm family and its livestock.

Although an all iron plow was patented by Newbold in 1797, the gain in efficiency that it provided was not sufficient to overcome the cost advantage of the bar-share, which most farmers could make themselves with the assistance of a blacksmith (Schlebecker 1975), and few iron plows were adopted.<sup>3</sup> But, the design was improved,<sup>4</sup> which increased its efficiency, and, when the social and economic context changed, the iron plow was rapidly adopted.

The socioeconomic situation changed in two respects. One was the opening of the interior of the American continent to settlement. Here the soils were heavier, the land was less uneven and larger fields were possible, and sturdier and more efficient plows were needed. Moreover, the nation's population was growing rapidly, and in the East coast cities, the demand for grain was expanding. By 1820 the stage was set for a

farming revolution in which grain growing (especially wheat) for the commercial market became increasingly important (Danhoff 1969).

In older as well as newer settlement areas, the shift from subsistence to commercial agriculture was signaled by the adoption of the iron plow. "Between 1830 and 1845, from Massachusetts to Indiana and from Maine to Alabama, the iron plow was adopted nearly everywhere" (Schlebecker 1975, 99). The shift was radical in two respects. First, it inaugurated a new and different technical frame for breaking ground, which led to different technical frames for preparing a seedbed, cultivating, and harvesting. In this respect, the iron plow was the centerpost of a fundamentally different technical system of agriculture. Second, and of equal significance, the adoption of plow culture was adaptive only if at the same time the farmer created a different farming system oriented to the market sale of crops and livestock products. The new farming system was based on a different set of ruling precepts and requirements.

With dependence on the market, productivity soon became a ruling precept. In grain growing, field size was an important limiting factor. Where topography permitted larger fields, productivity was determined by the efficiency of the plow in starting the cropping process. The cast-iron plow was more efficient in doing this than the wooden plowshare.

The immediate benefits of the cast-iron plow were that it moved through the ground more easily and "hence required fewer animals: one yoke of oxen could do the work equal to two or three with the wooden plow" (Danhof 1969, 189). Once the prairie sod was broken, horses, which worked faster than oxen, were preferred. The manpower needed for plowing, moreover, was reduced from two or three to one. Consequently, "the amount of work which a farmer could do in a day increased by 50 percent to 100 percent, or from an acre a day to an acre and a half or perhaps two acres a day" (Schlebecker 1975, 100). This made possible an increase in farm size, an accompanying decline in the cost of grain production, and an increase in its profitability. These benefits sparked further technical improvement in plow design, notably the development of the steel plow.<sup>5</sup> Eight decades later, the tractor's greater efficiency in plowing proved decisive in replacing the horse (Ankli 1980).<sup>6</sup>

The use of improved cast-iron plows signaled the increasing dominance of the concept of turning (rather than stirring) the soil as "plowing" and as the best strategy (goal) for preparing a seedbed (Danhof 1969). Both technical and economic considerations were involved in this decision. Not only were farmers able to prepare more ground with the iron plow, but also plowed ground facilitated subsequent machine tillage and planting operations. The importance of a clean plant bed,

however, was a development for which the requirements of the new machine technology was only partly responsible. Also important was the pressure to maintain yields and reduce costs.

With commercial production of small grain, the cost of seed, plant establishment, and maintaining yields on continuously cropped fields quickly became management concerns. Thus, in the 1840s and 1850s, Pennsylvania farmers began to invest in grain drills, which used less seed than the broadcast method and placed seed uniformly at the proper depth, and to experiment with fertilizer applications. Midwest farmers soon began to follow their lead (Danhof 1969). The knowledge gained in the use of a grain drill reinforced the importance of starting with a plowed field and a finely prepared seedbed. This point was emphasized in 1852 by a writer in the *Cultivator* (IX: 38–9, quoted in Danhof 1969, 213):

It certainly cannot be questioned at this day, but that drilling in wheat possesses many valuable claims over the broadcast system of sowing grains. . . . This, however, like most other branches of improvement, requires great care in its management. It ought not be attempted by a slovenly farmer—and unless the ground be previously fitted for the process, it would be unwise to attempt to use the machine.

There can be little doubt that the distinction between a careful and a “slovenly” manager was not lost on the *Cultivator*’s readers.

Turning the soil so that no ridges (except the headland), valleys, or surface residue remained made further tillage and planting easier and more effective. With a bull-tongue plow and a team of horses as his tools, creation of a clean plowed field signified high craftsmanship. Even after tractors replaced horses, a plowed field with a straight furrow and no surface residue showing continued to be an object of a plowman’s pride, as one former farm boy recalls (Dillman 1996):

Two shiny blades . . . , behind our little Ford Ferguson. The sound of the motor pulling all out, trying to be sure never to leave a line of uncovered grass, keeping the line straight so that no one could see a curvy last furrow.<sup>7</sup>

With tractors and the more powerful secondary tillage equipment then available, however, there was less necessity for plowing craftsmanship.

Not only were farmers forced to develop greater skill in using their equipment, they had a different strategy (goal) in developing a plant bed. The transition was not easily or quickly made. In newly settled areas, where capital was scarce and the rich prairie sod provided an abundant harvest, interest in and the acquisition of equipment for care-



ful tillage and planting came slowly (Bogue 1963; Danhof 1969). As Danhof (1969, 214) puts it: "At least a generation was required to bring farming on the prairie to what may be termed a stabilized level, with all land in use, soil and climate factors at least reasonably well understood, and profit calculations reduced to a fairly narrow margin." Then farmers became concerned with restoring fertility, careful tillage, and use of the grain drill. In many midwestern areas, this improvement in management during the second half of the nineteenth century was abetted by a "greater diligence in husbandry" brought by waves of Germanic and Scandinavian immigrants (Salamon 1992).

Tillage strategy (that is, the type of plant bed or landscape one aims to prepare) also depends on environmental conditions. This is hardly surprising because technical strategy is only useful insofar as it succeeds in modifying the particular environment to serve human ends. In this case, the high plains environment forced a substantial revision in plow culture. In the semiarid environment, the goal and strategy of husbanding moisture for cropping were as important as the preparation of the plant bed itself. The initial adaptive strategy, widely advocated by a successful South Dakota farmer, was deep plowing, a packed subsoil, harrowing to kill weeds and create a dust mulch, and a one-year fallow to build moisture (Hargreaves 1993; Adelman 1992). Before planting, a field might be rolled, or packed, to enable moisture to come closer to the surface. Eventually, however, only fallowing was found to be effective, and strategy and technique changed.

As the twentieth century progressed, farmers began replacing the moldboard with the disc plow. It had two advantages: First, the disc plow required less power than the moldboard and could be used when the ground was too hard for the moldboard to plow. Second, the small amount of stubble left on the surface tended to reduce wind erosion but with subsequent tillage would not interfere with drilling (Malin 1936). Although the farmer's interest in leaving some stubble to reduce wind erosion was doubtless of secondary importance, it represents an innovative response to the problem of soil erosion—a problem that would take several decades of attention to find effective and practicable solutions.

Removing crop residue or breaking sod and loosening the soil for subsequent tillage were not the only objectives in plowing (table 3.1). The total destruction of weeds and crop regrowth were also important aims. By controlling weeds and crop regrowth in fallow, a farmer could effectively eliminate any contamination or competition with subsequent crops. However, attainment of these objectives involved a trade-off. By cultivating fallow ground, the subsoil was exposed to drying, and the tilled surface was vulnerable to erosion. Recognition of this problem led

Table 3.1. Factors affecting performance of domestic crops.

- 
1. Ground cover: Grasses, volunteer crops, weeds, crop residues
  2. Weed competitors: Types, adaptiveness
  3. Climatic factors: Temperature range, rainfall distribution and intensity, growing season length, wind velocity
  4. Insects and plant diseases
  5. Soils: Structure, porosity, acidity, fertility, etc.
  6. Production factors: Land, labor, capital, technology
- 

to efforts in the first quarter of the twentieth century to develop tillage equipment that cut the weeds but left any crop residue on the surface. This effort resulted in 1920 in manufacture of the rod weeder (Shepard 1975) and two decades later of the discer (Isern 1988). These adaptive developments in tillage technology, along with the disc plow that preceded them, signify recognition of the erosion problem that plowing exacerbates and the efforts to develop adaptive solutions to it.

Although tillage was the principal method of weed control in plow agriculture, it was not the only one. Weed and disease control were among the aims of the cultural practices employed in rotating crops. Farmers learned that rotation of legumes and cover crops not only protected the soil but also increased its fertility. Crop rotation also had the benefit of disrupting the weed and disease vectors associated with a particular crop. Moreover, farmers experimented with crop spacing until optimum distances were established for high yield, but also so that the crop canopy would suppress weed growth.

The advance of strategy and style in plow culture also varied by the crop. In corn-growing areas before 1830, the planting practice was to draw a shovel plow across a previously "plowed" field at 3 or 4 foot intervals and then repeat the process at right angles. Corn was planted with a hoe where the furrows intersected (Danhof 1969). When plows became common, farmers threw two furrows against each other and planted corn with a hoe on the ridge. This process was laborious and time consuming, and led to the development of various types of hand planters. But none improved planting efficiency, and they were not widely accepted. It was not until the 1850s that a beneficial two-row corn planter was invented. Expanding row cultivators, which appeared in the 1830s, evolved into straddle-row cultivators in the 1840s and were widely adopted by midwestern corn farmers by the 1860s (Schlebecker 1975).

When the tractor became the source of power, plowing technique changed, and its efficiency increased severalfold. The strategy and

importance of plowing, however, changed little. Plowing was valued as a means of managing surface trash, aerating the soil (the first step in preparing a good seedbed), leveling the field, improving the physical condition of the soil, and controlling insects and diseases (Phillips and Young 1973). In preparing a plant bed with tractors, farmers were finally able to exhibit a finely tilled landscape that was the acme of craftsmanship, which generations of farmers had upheld. Unfortunately, by reducing the cloddiness of the soil surface, the much admired finely tilled plant bed became highly vulnerable to erosion (Nelson 1997).

As the twentieth century unfolded, plow culture in America had become a mature system in its strategy and technical principles for coping with natural forces of soils, weeds, and climate. These forces were formidable (table 3.1). To plant a crop, the farmer had to remove existing ground cover, suppress weeds, insects, and diseases, and in a timely manner prepare the soil for planting. The latter required taking into account seasonal weather and temperature conditions and, with available labor and equipment, to work the soil into a finely tilled seedbed adding along the way the necessary nutrients to enrich the soil. These forces varied from field to field and season to season, and crops differed in their seedbed requirements. Emblematic of the effectiveness of plow culture is its flexibility in enabling a farmer to cope with these multiple requirements. The flexibility is a function of the many options available to the farmer in coping with highly varying conditions of soil, crops, and weather (Parsons 1967).<sup>8</sup>

The practice of plow culture rests on five core beliefs.

1. Plowing is necessary to clear the field of surface residue, aerate the soil, and improve soil structure.
2. Burying surface residue suppresses plant diseases, insects, and weeds.
3. A clean plowed surface facilitates cultivation to level the ground, destroy weeds, and break up clods for a finely tilled seedbed.
4. Plowing and cultivation are the most cost-effective methods of controlling weeds and of preparing a proper plant bed for the tiller or row planter.
5. As a central activity of farming, plowing symbolizes and validates the farmer's role in society; one who performs his craft well gains prestige and enjoys feelings of self-worth.

Except for the extremities of wind and water, plow culture undergirded a sustainable system of agriculture, especially when integrated in a system of mixed crop and livestock farming (Logsdon 1984). The principal innovations in farming practice during the first half of the twentieth century

(such as gasoline-powered tractors and more specialized farm machinery), the use of lime, chemical fertilizer, and in higher yielding varieties of seeds, served to reinforce and cement these principles. The weaknesses of plow culture, however, became increasingly apparent as tractors became more powerful, the acreage under crop became larger, and farmers succumbed to the lure of greater profits through specialization in raising commercial crops.

Despite the growing chorus of discordant voices, however, plow culture was not seriously challenged until the 1930s, and high school vocational agriculture students in the 1950s were still being advised that one of the “better farm practices” was the preparation of a good seedbed. As the authors (Roberts et al. 1956, 31) of a popular text put it:

[This] usually involves cleaning up the land and getting it ready for plowing; plowing or breaking the land; pulverizing the soil; compacting the soil; and any other farm practices necessary for getting the land ready for planting.

They recommend turning under weed and crop residues, rather than burning them, and avoiding deep plowing; they go on to observe that:

[p]lowing alone will not provide a satisfactory seed bed. Studies have shown that a well-pulverized, smooth, and firm seed bed provides the most satisfactory conditions for growth. The smooth, well-pulverized condition enables the farmer to plant more uniformly and cultivate more evenly. (Roberts et al. 1956, 34)

But, some farmers on the plains were already using different tillage practices, and notions of different row-crop tillage methods were being tried in the Midwest.

## Plow Culture in Australia

The first Australian settlers in the last quarter of the eighteenth century used a simple hoe agriculture. Slowly, plows replaced the hoe, and during the second quarter of the nineteenth century, a new, more efficient, animal-powered, agriculture became the norm (Pratley and Rowell 1987). This system continued to evolve, first by incorporating European ideas and then American.

As in America, plow culture in Australia began its ascendance through the use of the heavy wooden plows, which had a sharp coulter and sharp moldboard edge, to break new ground (Pratley and Rowell 1987). With a team of twelve oxen, a farmer could plow as much as 1.6 hectares (4 acres) a week to a depth of 25 cm (10 inches). By midcen-

ture, lighter iron plows, which were made in Australia, replaced the heavy breaking plow.

Distinctive ecological conditions in Australia contributed to several innovations in plowing equipment. Unlike in the prairie areas of the United States, commercial wheat farming in Australia was possible only after a large acreage was cleared of trees and brush. Stumps, tree roots, and stones interfered with the use of ordinary plows, and removing them from large areas was a huge problem in a labor-short country. To help solve this problem, Richard Bruyer Smith in 1876 developed the stump-jump plow, which is the main Australian contribution to sod-busting technology (Pratley and Rowell 1987). It had a hinged plowshare, which released when meeting an obstruction and reset when the obstruction was passed. By facilitating the tillage of scrub and stoney lands, it speeded the settlement of new areas and rural towns. The mechanism was subsequently adapted to other types of tillage equipment.

Australia lacks the winter freezes that in northern climes break up the clods formed in heavy, clayey soils by the moldboard. Because of the clodding problem, some Australian farmers in the 1890s began using a "digging plough, which had a high short mouldboard to break up the sod as it turned over in the furrow" (Pratley and Rowell 1987, 4). But, a better solution was provided in 1906 by the Sundercut stump-jump disc plough. It combined the American innovation of rolling discs to break and turn the soil and the Australian stump-jump action. With the Sundercut, Australian farmers had a tillage implement that worked efficiently in relatively dry or heavy soils whether or not they were fully cleared, and left some surface residue to reduce erosion. It remained the primary tillage implement until the 1970s.

Late in the nineteenth century and early in the twentieth century, a variety of secondary tillage implements, including the scarifier and skim plough,<sup>9</sup> were developed for controlling weeds in fallow. After 1900, disc cultivators were used to break crusted surfaces, disturb weed growth, and break up clods.

Broadcasting seed remained the principal method of sowing until early in the twentieth century, when interest in producing wheat for export encouraged farmers to try to increase yields and reduce production costs. Then Australian farmers began investing in drills, as American farmers had begun doing a half-century earlier (Pratley and Rowell 1987; Shaw 1990).

Dry farming techniques—plowing, preparing a dust mulch, and a long fallow to store moisture—which had been developed in the United States, spread with relative rapidity to Australia. Although deep plowing and maintenance of a dust mulch with frequent harrowing were advocated as the best ways to conserve moisture and prepare plant bed, the

efficacy of deep plowing was questioned and largely abandoned by World War I. The superiority of a long (fifteen months) fallow was also not supported by research and was soon abandoned in favor of normal (eight to eleven months) fallows (Pratley and Rowell 1987).

Although with the Sundercut, farmers could handle substantial straw residue, heavy straw left on the field could clog and delay plowing or result in uneven plow depth. Burning the straw solved this problem and facilitated preparation of fallow:

Burn the stubble and start the cultivator to work immediately after the removal of one crop for preparation of the next. Plough at the first opportunity where the ground requires ploughing and keep the soil in a well-worked condition to maintain a weed-free blanket mulch to check the loss of soil moisture due to excessive evaporation. (Queensland Agricultural Journal, December 1925: quoted in Skinner et al. 1977)

The complete removal of stubble and preparation of a dust mulch had predictable consequences for erosion.

In the marginal areas of South Australia and West Australia, exposure of the light (Mallee) soils to drying winds during fallow periods resulted in ruinous soil erosion (Pratley and Rowell 1987). Fertility declined, yields dropped, and during the 1930s many farms were abandoned. Although less disastrous in other wheat-growing areas, such as northern New South Wales and Queensland, erosion rates climbed as cropping spread after World War I (Skinner et al. 1977). Nevertheless, little change occurred in the prevailing plow-cultivate tillage system until after World War II.<sup>10</sup>

## Plowing and Society

Plowing was the essential first step in producing crops and, by extension, to making a living from farming. The performance of this essential task, therefore, was an important component of a farmer's role in family and community. Within community, performance of an important role elicits pleasurable emotions and wins praise from peers and dependents. The poet Jesse Stuart (1934, 81) apprehends the joyous visual sensations of springtime plowing:

I love to watch the cool sod turning over,  
I love to plant my corn in middle April,  
When crows are building on adjoining hill  
And try to measure the bright April weather—  
Oh, I do wish Spring would go on forever.

Such rewards reinforce identification with the plowman's role and evoke pride in its skilled accomplishment.

It is not merely the significance of plowing in initiating life-sustaining processes, however, that arouses such sentiments; its importance also stems from its communal significance. Plowing was the central act in a social drama in which the farm community itself was sustained. It undergirded the economy. Being essential to it, plowing resonated with deeply held community values (Salamon 1992). In this respect, the plowman plowing is doing cultural work; in plowing, the plowman is helping recreate the sociocultural basis as well as the material basis of community. These sentiments help sustain its continual practice.

We should not be surprised then to find that plowing symbolized manhood, husbandry, and other important aspects of a farmer's collective identity.

Plowing is a demanding task, made more so by the aim of turning the soil so that no ridges (except the headland), valleys, or surface residue remained. With a bull-tongue plow and a team of horses as his implements, the farmer was able to create a clean plowed field, signifying high craftsmanship and the artistry of a master plowman, which required a powerful and sensitive hand, and the steady pace of a trained and cooperative team. Because of the physical strength required in handling the plow, oxen, or horses, plowing is primarily done everywhere by men.

Growing up, a boy follows his father and the team, feeling the cool, moist soil on the soles of his bare feet as he walks in the freshly plowed furrow. He learns to harness, hitch, and guide the team, or service and drive the tractor. One day with his father's encouragement and supervision, he mounts the plow seat, and with a "Gid-e-yap" and pull of the reins steers the furrow horse down the row, releasing the plowshares as he completes a turn, and attempting as he goes to turn the soil as smoothly and evenly as his father had done before him. His physical strength and proficiency in performing this task certify his dawning manhood in the family and farm community. The significance of plowing as a youthful badge of manhood was not much diminished by the substitution of the tractor for the horse; only the technical skills were changed.<sup>11</sup> Eventually, skill in plowing came to be promoted at state fairs and on special occasions by specialized groups.<sup>12</sup>

In certifying the person's competence as a farmer, plowing labeled him as a particular kind of farm man. Plowing signified agricultural purpose; it was the mark of both civilized man and civilized nature.<sup>13</sup> On the one side, the ploughman<sup>14</sup>—"those who labor in the earth"—was the central figure in Jefferson's vision of the independent, rational, democratic yeoman. As Jefferson and the legion of agrarians following in his wake saw it, the yeoman working his land was admirable primarily for his robust self-sufficiency and special "rural" virtues of honesty and hard work.<sup>15</sup>

Although the yeoman himself may have been primarily interested in making money, as Hofstadter (1956) claims, the values of freedom, independence, and hard work tilling the land have remained an important component of farm culture and social identity. For farm youth in the twentieth century, these sentiments were succinctly expressed by Fannie R. Buchanan in *The Ploughing Song*, a staple of 4-H Club and FFA meetings:

Sons of the soil are we, Lads of the field and flock,  
Turning our sods, asking no odds, Where is life so free?  
Facing the dawn, brain ruling brawn, Lord's of our lands we'll be.

The emphasis on independence and family have been, and in many aspects remain, a major component of the farmer's collective identity in Australia (Craig and Phillips 1983) as well as in the United States (Dalecki and Coughenour 1992; Coughenour 1996; Montmarquet 1989). The meaning of land as an instrument of the family farm, however, has undergone much change historically, and varies by type of farming community and family background (Bennett 1969; Salamon 1992). English colonists in Australia and America brought complex beliefs with respect to the land they were settling. Of foremost importance, possession of a legal title to land conveyed citizenship rights and social status in community. For the indentured servants, freed convicts, and ordinary immigrants, having title to land meant nothing less than the elevation to full personhood in society. In economic terms, it meant the unfettered opportunity to enjoy the fruits of one's own labor. For the family, land ownership meant lifelong security.

For the "yeoman" title to a particular piece of land, a "place" provided a crucial element in one's sociopersonal identity. Sonya Salamon (1992, 101) quotes an Illinois farmer: "Your land is really a part of you. Selling it would be like cutting off your right arm." A person or a family is known by the farm it owns and operates (e.g., "The Nelson place"). The longer and more successfully the farm is operated by a family and its heirs, the more established in the collective memory of the community it becomes. Preserving the place and protecting the family livelihood and social status become one and the same thing. In this way, the farm becomes part of the family's heritage, something to be conserved. If membership in an ethnic community is part of this heritage, then identity of place incorporates the family in the historic community (Bennett 1969; Salamon 1992). This orientation makes husbandry of the land of supreme importance.

From early in the nineteenth century to the middle of the twentieth, Australian and American farmers believed that in developing "virgin"



land for agriculture, they were contributing to a vital national purpose. In hewing the forest or breaking prairie sod, they were transforming the raw, unusable wilderness to a valued agricultural resource. In breaking the sod, the husband-man tamed the wilderness, bringing its energy and fruitfulness under human control for the better service of human needs and civilized purposes (Marx 1964). The ideal that Jefferson described in his *Notes on Virginia* was nicely captured by Whitman (1982, 224) in *Pioneers! O Pioneers!*

We primeval forests felling,  
We the rivers stemming, vexing we and piercing deep the mines within,  
We the surface broad surveying, we the virgin soil upheaving,  
Pioneers! O pioneers!

As we have seen, plow culture has both a central core of technical and social meanings. In breaking the sod, the farmer facilitated the development of subsurface humus (bringing up what buried last year) and prepared the plant bed for placement of supplemental fertilizer and seed, infiltration of water, and penetration of new roots. At the same time, in “working his ground,” a farmer both created a valuable resource for economic crops and validated his social mandate as a farmer.

Despite the social significance of land to some ethnic groups and in older settled communities, land in the “Yankee” tradition primarily had economic significance (Salamon 1992). In the northern states, the economic meaning and significance of land were encouraged by the lack of a landed gentry class, the development of the land market, speculation in land, and the growth of commercial farming. As Marty Strange (1988, 46) puts it: “Land changed from being a place to employ one’s labor to a place to employ one’s capital and technology.” Although the era of “Bonanza” farming, which best exemplifies land viewed as an economic commodity, was short lived (Shannon 1945), this type of business orientation remained pervasive. As Salamon (1992) says of Illinois “Yankee entrepreneurs,” the family is committed to the farm business rather than the farmstead. At any given time, land, like stocks, may, or may not, be a “good” investment. (If it is not, good rental land can generally be found.) The symbolic value of land thus is primarily its financial worth. Like other capital, it may depreciate over time. If so, a farmer has the choice of investing in its improvement or of finding other land of suitable worth.

Information on soil-building techniques through use of manures, compost, legumes, and the like was widely available, and various soil-improvement practices had been common in the local agricultural societies from which most Australian and American farmers had come

(Danhoff 1969; Pratley and Rowell 1987). But, as Danhoff (1969) notes, these practices were discarded as neither necessary nor practical by the pioneer settlers of virgin lands. They were not necessary because the fertility of the virgin soils insured adequate crops for years, sometimes decades. Moreover, the cost of acquiring new virgin land to replace worn-out land was relatively small. Fertility-maintaining practices were not practical because the payoff from the investment of labor and capital in the construction of houses, barns, and fences and in the acquisition of livestock was far greater (Bogue 1963; Danhoff 1969).

The availability of land for commercial agriculture on the frontier when combined with plow culture thus provided the conditions and incentives for widespread exploitation of soil resources during the nineteenth century.<sup>16</sup> This outcome was not unique to America. A similar situation existed in Australia (Shaw 1990); indeed, resource degradation is a common consequence of frontier commercial agriculture (Margolis 1977).<sup>17</sup>

Plowing is not an isolated act but occurs in a socionatural context. In areas where corn is the staple, plowing was often done as early in the spring as possible. The springtime sounds and images envelope the ploughman, and plowing comes to symbolize spring itself. The Kentucky springtime images associated with plowing are nicely recorded by Stuart (1934, 81):

I love to turn the cold bare March sod over,  
 I love to run the fresh earth down the hill,  
 I love to have my ground in shape to plant  
 About the coming of the whippoorwill.  
 Few days before the blooming of the clover  
 The plowing must be done when April's over.  
 The mules work better in cool days of Spring—  
 Better to work when larks first start to sing.  
 I hate to think I'll ever lose a Spring!

In middle-America winter wheat-growing areas, plowing is a late summer and early fall activity. It is associated with images of August sun and sweat, the wheat stubble of harvest past, dust devils and summer storms. For farm boys growing up with a tractor and plow, the growl of a Farmall, Ford Ferguson, or whop-whop of a John Deere, the smell of exhaust and freshly turned earth, the tripline and double plowshares remain indelible images. Round after round spooked nesting meadowlarks and nearly grown jackrabbits, and always the narrow furrow neatly separated the shrinking stubble land and the expanding black earth.<sup>18</sup> In the more northerly spring wheat areas, postharvest plowing took place later in the

fall when grey skies, chilling winds, and flocking birds signal approaching winter.

In marking seasonal planting rhythms, plowing inaugurates life-giving processes. In contemplation, plowing thus elicited emotions aroused by universal processes of life and death. Whitman (1982, 394) captures this pervasive feeling:

As I watch'd the ploughman ploughing,  
Or the sower sowing in the fields, or the harvester harvesting,  
I saw there too, O life and death, your analogies;  
(Life, life, is the tillage, and Death is the harvest according.)

From this sense of the ultimate verity, which plowing reveals, it is but a short step to recognize in the plow and its workman the embodiment of divine purpose. This relationship was acknowledged by *The Progressive Farmer*<sup>19</sup> in 1946 in reporting a ceremonial "blessing of the plow" in Chichester, England, with the hope that the practice might be emulated in the United States. The ceremony, led by the bishop, of the Chichester (Protestant Episcopal) Cathedral, included a Young Farmers' Club member who "expressed thankfulness for God's gifts:—*The rich soil and smell of fresh-turned earth. The clatter of the tractor and gleam of a cutting edge. The seamed hand, the knotted arm, the sweat of the brow, the skill of the ploughman.*" After hymns and prayers of thanksgiving, according to this descriptive report, a ploughman in a dark jacket asked the bishop to bless the plough painted silver, blue, and red, which had been carried to the chancel steps. While the ploughman and eight young farmers in white milking jackets knelt around the plough, "The Bishop, his hand raised in blessing, stood above it in a shining cope of green and gold. Behind it was the great many colored east window of the Cathedral, through which a shaft of winter sunshine gave added colour and meaning to a simple, age-old scene."

Ploughing thus contributed substantially to the collective identity of the yeoman farmer—who he was, what he did, and why he did it. It gave him social purpose and helped make the yeoman a central figure in moral society. From plowing, the yeoman developed not merely resources for agricultural production but importantly pride in his work and a sense of rectitude. These moral sentiments, in turn, reinforced the commitment to plow culture and its technical frame. Any alternative technical frame must also be able to provide an equally potent cultural identity and moral purpose.

Despite its importance to grain growing and to rural prosperity in wheat and grain-growing areas of Australia, plowing never became as prominent a symbol of agrarian culture in Australia as it did in America.

Doubtless, this is largely because in Australia sheep and cattle grazing, the grazier and the “jolly swagman,” rather than the farmer, were the pioneers and became the stuff of pioneering legend and nation building. Even today, “dirt” farming earns less social prestige than “grazing” and is rarely an object of veneration. Nevertheless, in grain-growing areas, proficiency in plowing was an elementary skill, recognized as an important credential of farming maturity. The activity marked the seasons, as it did in America, and signaled the preparation for a new cycle of life. Although plowing did not provide the Australian farmer with as an important a social identity as it did the American farmer, plowing and cultivation were necessary technical operations to commercial grain-growing success. Plow technology, therefore, had social as well as economic importance and could not be given up until better alternatives were available.

### *Supporters and Advocates*

Plowing was an activity of the farming community. All farmers engaged in it, and almost all believed plowing was necessary and good. In farming areas, the social network thus included the entire rural community. Even those for whom dairying or livestock was the principal farm enterprise often plowed to raise hay or grain or to improve pastures, and thus participated in plow culture. But, for the livestock farmer or rancher, nature had a different face than for the farmer. For the latter, as Bennett (1969) points out, nature in its original state is a “wilderness,” which must be tamed and domesticated. By contrast, for ranchers and graziers, nature—although wild—is benign and friendly. For the latter, plowing is clearly what “dirt” farmers do and conveys negative moral sentiments; it is symbolic of a way of life less mindful of, and in tune with, nature than grazing.

Although farmers socialized their sons and daughters in plow culture, plowing also had staunch advocates outside. State fairs and organizations such as the World Championship Ploughing Organization supported international ploughing contests, which promoted the idea and craft of plowing (Hall 1992). Another consists of the agricultural extension or advisory agents and more generally the state and national agricultural services. Many representatives of these institutions clung to the belief that plowing and tillage were essential to proper plant bed preparation well past the time that innovative farmers had demonstrated the feasibility of conservation tillage ideas and practices.

The second and, in some respects, more formidable set of advocates of plowing (and adversaries of conservation tillage) were machinery companies. They had an economic stake in powerful tractors, large

plows, and tillage equipment, and in planters that operated effectively in tilled ground. They promoted conventional tillage and planting equipment through advertising, displaying such equipment at state fairs, and sponsoring tractor plowing demonstrations. Moreover, they slowed the advance of conservation tillage by delaying investments in the development of appropriate, alternative equipment that could render obsolete investments in the production of conventional tillage and planting equipment.

## Notes

1. The kind of decision unit, of course, varies from an individual to a corporate or governmental decision unit.

2. For a revealing essay on the plow culture complex, see Lewis (1949).

3. The Newbold plow was made in a single piece, which meant that, if one part broke or the share became dull, the entire plow had to be discarded (Schlebecker 1975). This design defect made it relatively costly and impractical.

4. Thomas Jefferson is credited with first attempting to develop a mathematical formula for plow design, and R. B. Chenoworth of Baltimore in 1813 patented a cast-iron plow with a separate share. Jethro Wood further improved this design in 1814 and 1819 (Schlebecker 1975). Compared with the farmer-made wood plow, the principal advantages of the cast-iron plow were twofold: (1) It moved through soil more easily, and (2) it could be replicated.

5. "In 1837, John Deere began making single, one-piece plows of wrought iron, with a cutting edge of steel on the share" (Schlebecker 1975, 103). By 1846, Deere and his financial partner Cecil Andrus were producing 1,000 plows a year and increased production tenfold during the following decade.

6. Reflecting the tractor's importance in plowing was the common practice of manufacturers of advertising the power of a particular tractor in terms of the number of plow-bottoms it could pull (i.e., two-, four-, or six-bottom tractor).

7. One of the authors can also recall his own boyhood pride in keeping the furrow straight as a mark of skill and as an indicator that the land had been plowed without skips. The social significance of craftsmanship in plowing is more fully explored later.

8. Parsons (1967) estimates that there are as many as fifty-five choices open to the farmer in using conventional tillage.

9. The scarifier is a wide, rigid, and relatively heavy cultivator that is used to stir and weed fallow ground before sowing. The skim plough, which was lighter than the scarifier, had a curved knifelike blade that ran 1 or 2 inches below the soil surface to cut weeds in fallow.

10. The system of dry farming in northern New South Wales and Queensland during the 1950s is further described in chapter 4.

11. The ability to cope with seasonal conditions, such as enduring summer heat and sun, or, in more northerly areas, the chilling winds of late fall, also measured one's manhood as Mark Nord (1998) notes: "November in North

Dakota could be frigid and windy, so that plowing became not only a necessary agricultural activity, but also a certification of one's hardiness. This was before tractors had cabs. . . . I remember a neighboring farmer telling of stopping for mid-morning coffee, pouring steaming coffee from his thermos into the plastic cup/cover, and wrapping his hands around the cup to warm them. 'In a minute or so I drank the coffee, but by then it was stone cold,' he said."

12. Plowing contests sponsored by the Iowa Soil Conservation Service were important events at Iowa State Fairs during the 1950s and 1960s. The World Championship Plowing Organization, established in Great Britain, held a championship plowing contest in Ohio in 1952.

13. The notion of agriculture as the instrument of civilization was widely used by writers, including Jefferson, who treated the pastoral life as an ideal model (Marx 1964) of civilized life and more recently by critics of modern, commercial agriculture (Berry 1977).

14. The English spelling "plough" and the American spelling "plow" are used interchangeably throughout this chapter.

15. The qualities of simplicity, strength, nobility, and God-fearing purpose of the plowman are admirably expressed in Louis Golding's "Ploughman at the Plough" (Harrington and Thomas 1929).

16. During the 1920s, *The Progressive Farmer*, while editorializing that most men of middle age could remember when the pioneer outlook toward mining the soil, instead of farming it, still existed, went on to conclude that attitudes had changed from a century earlier (Vol. 45, No. 21, May 24, 1930). To support the claim of a different attitude today, the editorial noted the common attitude in earlier days, as reported by Jeremiah Battle of Edgecombe County, North Carolina, in 1811: "The usual plan appears to be to clear, and put into cultivation, as large an extent of ground as practicable; and to exhaust it as fast as a series of grain crops can do it. A few years of this mode of culture renders it necessary to give it rest every other year; at which times it is either sown in small grains or abandoned to the weeds. It is at length entirely worn out, while other ground is cleared to supply its place" (*North Carolina Historical Review*).

17. Margolis (1977) analyzes the system of high-valued cash crop agriculture often found in frontier zones (e.g. tobacco, coffee, cotton, wheat, and corn). In such situations, the goal is to obtain the maximum production; land is used extensively rather than intensively, and its availability coupled with high-cost labor lead to land exploitation. Margolis (1977, 43) argues that resource degradation was the common experience of frontier societies when there was "(1) demand for a valuable cash crop, (2) the presence of free or inexpensive virgin frontier land, (3) unstable market conditions affecting the price received for the crop, (4) the accessibility of markets, . . . (5) the availability of credit." (6) Virgin land is cleared for cultivation, and (7) natural conditions—weather and insect pests—are unpredictable.

18. Dillman (1996) describes the images impressed in his memory: "Two shiny blades, 14 inchers, behind our little Ford Ferguson. The sound of the motor pulling all out . . . keeping the [furrow] straight . . . sitting sideways on the tractor seat so as to look forward and backwards, Meadowlarks watching

from fence posts, mental calculations of how many more rounds before dinner, the intoxication of freshly turned soil and exhaust; no shirt under the hot sun and no thoughts of melodrama, concern only about the incipient tan line that was a badge of honor.”

19. *The Progressive Farmer* (Vol. 61, No. 2, April 1946, p. 89). The ceremony was a “modern interpretation” of “Plough Monday”—the day after Christmas when men began ploughing again—which, according to the report, had not been held locally in 300 years.

# 4

## Farming in the 1950s: The Driving Forces

*Our soils are fertile, but our mode of farming neither conserves the soil nor secures full crop returns. . . . The greatest unnecessary loss of our soil is preventable erosion.*

—National Conservation Commission (1909)

*Modern soil conservation is . . . dynamic and progressive; it leads to increased and lasting productivity of the land. . . . It both increases the yields per acre and lowers the cost of production on most farm land.*

—USDA (1948)

*During the years after World War II, every aspect of the agricultural revolution rapidly accelerated. Major progress occurred . . . in mechanizing grain and forage production . . . in breeding of more productive crop varieties . . . [in] the wider use of chemicals for fertilizer, . . . insecticides, fungicides, and herbicides. [There was] growing specialization and a greater emphasis on modern management practices.*

—Gilbert C. Fite (1981, 110–113)

In Australia and the United States, plow agriculture became ascendant during the era of extensive agriculture at the end of the nineteenth century. In the decades following World War I, agriculture in both countries shifted irrevocably from extensive to intensive modes of production (Cochrane 1993; Shaw 1990). The revolution in the United States was precipitated by several factors. The initial impetus was the closing of the frontier, which ended the availability of new farmland. As the farm population continued to grow, farms gradually became smaller, making farming more labor intensive. The technology of extensive farming, which had been adaptive in the earlier era, gradually became less and less profitable. The cost-price pressures induced by these changes



impelled farmers to search for new technologies that gave promise of increasing land and labor productivity.

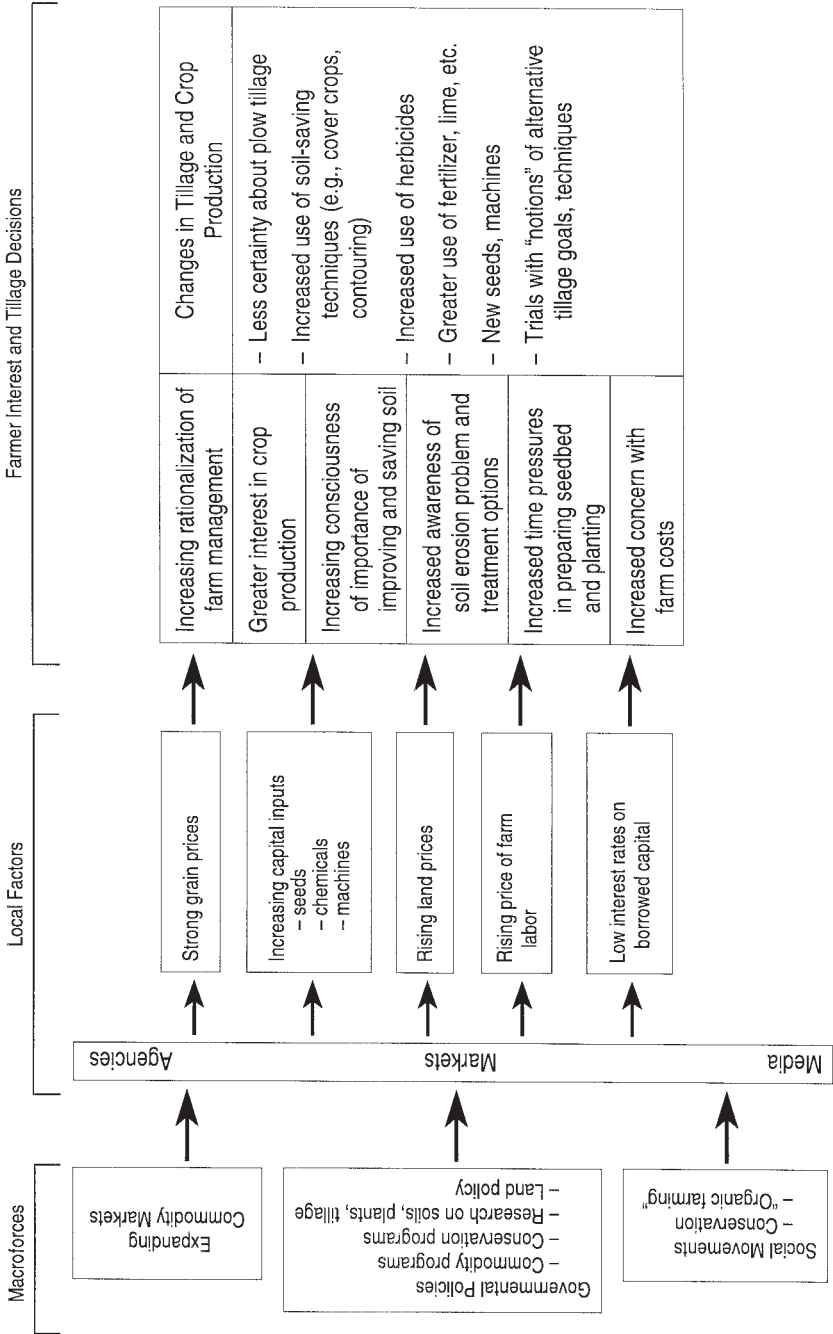
In this chapter, we discuss the changing nexus of forces affecting agriculture in the United States and Australia in the period between World War II and 1960. The trends during this period progressively destabilized the resource and cost-benefit basis of conventional plow agriculture. Meanwhile “notions” of different types of tillage systems sparked experimentation with new technical systems that saved both soil and input costs while maintaining crop production. Both processes set the stage for the innovation in tillage systems, which we describe in following chapters.

## The Forces

World War II had a huge impact in accelerating change in agriculture and setting the stage for further revolution in the postwar era. First, the onset of the war almost immediately altered the economic and political climate, which had been dominated by burdensome commodity surpluses, low prices, and policies of production limitation (Fite 1981). To feed soldiers, civilian workers, and allies, American farmers were challenged to increase production, and guaranteed prices at 85 percent of parity was the carrot. Second, the demand for manpower by the military services and wartime industry drained the surplus farm population. By the war’s end, five farmers were producing more than six had before the war. Finally, better prices and greater productivity provided farm families with a level of prosperity and a greater sense of optimism than they had known before.

During the decade following the end of World War II, the direction of change in agriculture, which the demands of the great war had induced, was sustained by the demands of the Korean conflict. Governmental policies, farm input, and commodity market prices continued to favor intensification of agricultural production. Expanding agricultural research stations, industrial laboratories, and extension advisory services sent forth a flood of new technologies: new seeds, chemicals, and machines.<sup>1</sup> Under the stimulus of these forces, American farmers continued the development of more capital-intensive and efficient systems of agricultural production (fig. 4.1). The structure of agriculture, especially in the Midwest and South, began to shift from predominately small-scale crop and livestock operations to larger scale, more specialized types of farms (Ball and Heady 1972; Schertz et al. 1979; USDA 1979b). Many farmers, guided by personal preference, favorable commodity prices and support policies, and ecological conditions, progressively expanded production

Figure 4.1. Model of major factors affecting farmers' tillage and cropping systems in the 1950s.



of grains and oil seeds (White and Irwin 1972; Coughenour 1980; Anosike and Coughenour 1990).

As productivity increased with the intensification of plow agriculture, the loss of valuable soil resources jumped alarmingly. The situation strengthened countermovements—interest in, and experiments with, minimum tillage and related technologies, as well as governmental soil conservation policies and programs. These forces gradually weakened the foundations of plow agriculture, setting the stage for the social construction of innovative conservation tillage systems.

The structure of agriculture in Australia following World War II was influenced by land resettlement of war veterans on relatively small properties. This policy came at a time when world market prices favored grain growing, with the result that there was a progressive shift—where soils and climate permitted—from extensive grazing of sheep and cattle to cultivation of export crops (e.g., wheat) (Gruen 1990). Associated with the conversion of grazing land to cultivated crops was an increase in soil erosion. Both farmer and public awareness of the destruction of soil induced policy changes and the development of technologies that were designed to foster more soil-conserving methods of farming.

## United States

By 1950, several patterns of development in American agriculture began to seriously undermine the technical, economic, institutional, and ethical foundations of plow culture. First, federal commodity policies as well as the intensification of production per acre, through use of higher yielding seeds and chemical fertilizers, increased the value of land.<sup>2</sup> But, with land values rising, maintaining and even increasing productivity became increasingly important, and pursuit of this aim increased the exposure of cropland to destruction by wind and rain. Second, with competition from industry for labor as well as demands by farmers for higher skilled labor, farm labor became increasingly costly.<sup>3</sup> At the same time, the end of the Korean War heralded a new era of commodity surpluses and low farm prices. Both factors put farmers under mounting pressure to produce more with less and less labor. Third, the heightened concern over the rising loss of an increasing valuable resource sparked the soil conservation movement and gave urgency to institutional change—expanded soil conservation programs—and to soil-conserving practices at the farm level. Fourth, armed with new information about soils, plants, and chemical weed control, researchers and innovative-minded farmers began to experi-

ment with “notions” of radically different tillage systems with soil- and labor-saving benefits as primary aims.

### *Farm Capital and Labor*

By increasing their investments in operational capital, farmers were able to use both their land and labor more efficiently. During the 1940s and 1950s, inputs of capital were boosted substantially. By 1950, capital inputs had jumped from 30 percent in 1940 to 54 percent of all farm inputs (exclusive of labor and real estate), and by 1960 the proportion had been raised to 58 percent (Tweeten 1979, table 5.3). Meanwhile, the index of crop production per acre—a measure of land-use efficiency—climbed from sixty-nine in 1940 to eighty-nine in 1960,<sup>4</sup> and labor efficiency in output per man-hour jumped from twenty to sixty-five (Tweeten 1979, table 5.6).

Although these developments were propelled by advances in agricultural science and technology, the incentive to invest in new technology was boosted by output-rewarding federal agricultural and tax policies (Schertz 1979b; Quance and Tweeten 1972). Farmers’ economic benefits from farm policies were proportional to the quantities of the covered commodities produced, which encouraged the use of productivity-enhancing inputs. The purchase of farm capital was further encouraged by investment tax credits and accelerated rates of depreciation. Several institutional developments, such as crop insurance, price support programs, and futures markets reduced the risk of relying only on crops or livestock. Moreover, improved factor markets enabled farmers to rent or hire services, rather than purchase expensive equipment, which also reduced the cost of expanding crop production (White and Irwin 1972).

At the farm level, rising costs for land and labor increased the incentive to expand productivity-enhancing capital investments. Farmers acquired larger tractors and machinery, new seeds, and chemical fertilizer, which reduced the need for crop rotations while increasing land and labor efficiencies.<sup>5</sup> Expanding grain markets and wartime demand boosted prices, and governmental price supports reduced risks of financial loss when demand slackened. The profitability of land and labor devoted to crops soared relative to land and labor devoted to pasture and livestock. The expansion of crop production was aided by the increasing rationalization of farm management, which occurred during the 1950s.<sup>6</sup> Analysis invariably indicated that the profitability of an acre of land in crops greatly exceeded that of an acre devoted to pasture or forage crops. The warnings of soil conservationists about the danger of soil erosion, the Soil Bank, and the promotion of fescue pastures on

sloping lands and livestock production were the major counterforces to the expansion of grain growing. Nevertheless, the result of the favorable economic climate in the 1950s was the progressive separation of crop farming from the raising of livestock (White and Irwin 1972).<sup>7</sup>

These institutional structures and the farmer's goal of maintaining profitability placed him on a "treadmill" of progressively investing in new technology and expanding the size of farming operations (Cochrane 1986). Unprofitable farms were sold to more profitable farmers. Farms became fewer and larger. Although the number of farms declined by 31 percent during the 1950s, the size of the average farm increased from 216 acres to 303 acres—40 percent.

### *Land and Conservation Policy and Programs*

The impact of agricultural development on land, however, was complex. Advances in the efficiency of plows and cultivators in removing weeds and surface residue simply increased the exposure of soils to the destructive natural forces of wind and rain. By the 1930s, 282 million acres (50 million acres of cropland) were estimated to have been "ruined, or seriously impoverished" by erosion (Bennett 1939). Moreover, half the topsoil was estimated to have eroded from another 100 million acres. Although farm leaders as well as farmers agonized over these losses,<sup>8</sup> only limited solutions to farming without plowing were available.

As a result of parity prices for basic grain crops and productivity increases, the value of land began to rise. Moreover, farmers who invested more heavily in tractors, equipment, and cropland progressively tended to focus more on crop than on livestock production. Although crop farmers thus became increasingly mindful of the value of their land as an economic resource, they were equally committed to using it for its highest valued purpose (i.e., cropping). This economic incentive to expand cropland put rolling to hilly lands at risk for rapid erosion unless protected by expensive terraces.<sup>9</sup> Unfortunately, grain growers found terraces difficult to construct and even more inconvenient in field operations.

But, other events were occurring that began to increase the options available to farmers. During the 1920s, Hugh Hamilton Bennett, a soil surveyor in the U.S. Department of Agriculture, made the destruction of soil resources and their conservation a national cause (Held and Clawson 1965).<sup>10</sup> In 1930, Bennett succeeded in persuading the U.S. Congress to appropriate funds for research on soil conservation methods, and he later persuaded the Roosevelt administration to establish an agency that later became the Soil Conservation Service (SCS). The agency began promoting demonstration soil conservation methods on individually

owned farms or ranches, but the course of the program changed dramatically in 1936 with the establishment of soil conservation districts. These “special districts,” authorized under state laws, provided a vehicle for federal monies to be used (Held and Clawson 1965, 47):

to carry on research for erosion control; to conduct demonstration projects; to carry out actual land conservation measures and programs; to enter into contracts with farmers and to give them financial and other assistance for conservation programs; to make gifts and loans of seeds, planting materials, and other supplies, and lend equipment to farmers, for these purposes; to construct and maintain structures; to develop land-use plans for the districts and for farms; and to carry out other related programs.

Other agencies soon began establishing their own claims to promoting soil conservation (Rasmussen 1982; Held and Clawson 1965). With a mandate to regulate production, the U.S. Department of Agriculture, under various administrative agencies, established the Agricultural Conservation Program (ACP), which gave farmers income supplements for approved soil conservation practices. The Tennessee Valley Authority and the Great Plains Conservation Program developed regional programs of land and water use and control.

With various administrative authorities delving into the soil conservation issues, there were frequent conflicts over objectives and means of saving soil as well as areas of responsibility. Turf battles were especially bitter between the USDA agencies (SCS and ACP) and the State Extension Services. The agencies contested the efficacy of specific practices as well as of the whole-farm conservation plans prepared by SCS. These conflicts contributed to confusion, missed opportunities, and waste of financial resources (Hardin 1952; Held and Clawson 1965; Rasmussen 1982).<sup>11</sup>

Despite these difficulties, the soil conservation programs made notable progress during its first two decades in addressing the erosion of the nation's soil resources. Based on data from the 1958 Conservation Needs Inventory, Held and Clawson (1965, 169) conclude that “39 percent of the Class II and III land expected to be used for crops in 1975 had been adequately treated.” Equally important, they conclude that a sea change had occurred in farmers’ as well as public attitudes about soil conservation. Although in 1930 few farmers, or agricultural advisors for that matter, were aware of, or concerned about, erosion hazards on their farms, by the 1950s and 1960s “most of the nation . . . [had become] ‘soil conservation conscious’ ” (Held and Clawson 1965, 231). Meanwhile, a substantial cleft appeared between the attitudes of SCS

technicians about the seriousness of the erosion hazard and their knowledge of treatment options and that of most farmers.

In some respects, soil conservation program recommendations—with their emphasis on soil management and plow culture—were mutually sustaining. In rolling to hilly country where mixed crop and livestock farming prevailed, crops were grown for livestock feed primarily, only secondarily for sale. Conservation measures—converting sloping land to grass and legumes, contouring and strip crops, building waterways, ponds and check dams—fit nicely with livestock production. In Kentucky, in Tennessee, and along the Ohio River Valley, the soil conservation program gave a boost to planting fescue on sloping fields and raising beef cattle or dairying and tobacco. Farmers felt these enterprises were best-suited to the local area. Keeping sloping fields in grass or forage crops, contouring, and terraces and the economic benefits of these practices were staunchly supported as “good” practices by the leading farm papers in the upper South and Midwest.<sup>12</sup>

This general complementarity of conservation and crop-livestock farming systems also held in other areas, such as the high plains. In reviewing national progress in soil conservation, Held and Clawson (1965, 232) estimated that by 1957 somewhere between 20 and 60 percent “of the soil conservation job as it existed in the early or mid-thirties had been accomplished.” But, cropland acreage was expanding, and the scope of the soil conservation problem was increasing.

Despite the complementarities, farmers were notably reluctant to adopt best soil management practices. Studies indicated that tenure, labor, capital, and current income needs and price uncertainties constrained farmers in investing in soil-conserving practices (Held and Clawson 1965). The cost-effectiveness and/or practicality of recommended conservation measures, moreover, was often undercut by the elusive nature of much soil erosion.

In 1956, the U.S. Congress aimed to solve both the problems of commodity surpluses and conservation by establishing a “Soil Bank.” It had two parts—a conservation reserve program, which paid farmers for contracting to keep specified cropland in conservation use only for up to 10 years (i.e., conservation reserve), and an acreage allotment program.<sup>13</sup> In 1960, 28.6 million acres were under contracts for up to 10 years (Rasmussen 1982). Thus, this program was quite successful in shifting erosion-prone cropland to grass or forage crops; however, by thereby subsidizing forage for beef cattle, it boosted beef cattle numbers, drove down cattle prices and profits, and contributed to the relative profitability of grain growing. This increased the incentive to plow soil-banked land as soon as the contracts expired, which undermined the

program's long-run objective of saving soil (Held and Clawson 1965). Even with the Soil Bank, concluded Held and Clawson (1965, 238), about "two-thirds of the total 1958 cropland area . . . [still] needed conservation treatment of some kind."

*Technological Ferment, "Notions" of New Tillage Frames,  
and the "Erosion" of Plow Culture*

Although the plowing and mechanical cultivation of fields, regardless of slope and rainfall conditions, remained the prevailing tillage system, several forces were already beginning to undermine the foundations of plow culture. Its central beliefs were being questioned, and some farmers were beginning to recognize that alternative techniques were sometimes more cost effective. These tendencies expanded and became more potent as the 1950s unfolded. By the end of the decade, contradictory knowledge and belief not only had substantially eroded consensual support among American farmers for plow culture's core beliefs, but also the components of several new tillage systems were being tested.

The initial challenge, already alluded to, was to the belief that turning the soil and burying all surface residue were the necessary first steps in preparing a suitable plant bed. The attack on this belief began in western plains areas, where wind- and water-ravaged prairie soils were plowed and cultivated for wheat and other small grains. In the early decades of the twentieth century, scientists and farmers began to recognize the value of stubble on the soil surface in reducing erosion, and a few innovators experimented with "subtillage," which left stubble on the surface and was more economical than plowing (McCalla and Army 1960).

Intensive research on stubble mulching was not started, however, until 1937 when the Nebraska Agricultural Experiment Station and the Soil Conservation Service began a cooperative research project on the effectiveness of stubble mulching in reducing erosion. That year, C. S. Noble in Alberta, Canada, also initiated studies with stubble mulching, which among other things resulted in development of the Noble sweep plow.<sup>14</sup> Research on stubble mulching soon spread with federal support to South Carolina, North Dakota, Texas, Iowa, Idaho, and Washington.

In a remarkably short time, substantial information was developed about the soil factors affecting wind erosion and the efficacy of stubble mulch. Crop residue was shown to decrease the force of the wind on the surface as well as the force of falling raindrops in dislodging soil particles. Crop residues anchored to the soil surface also tended to dam surface water, slowing its movement and aiding infiltration. Studies indicated that over a period of years soil loss on stubble-mulched ground was one-sixth as large as on plowed ground.



By 1950, research-based recommendations were available on the amount of stubble needed on different types of soils to control wind and water erosion (McCalla and Army 1960). The development of complementary machines, such as the chisel and Noble sweep plows, the rod weeder (Shepard 1975), discer (Isern 1988), duckfoot cultivators, and mulch seeders, enabled farmers in western wheat areas to save stubble and raise small grain crops successfully.

Meanwhile, the technical culture of plowing-clean cultivation-fertilizing-planting was attacked from two directions. On the one side, it was argued that amount of organic material in the upper soil strata was the mark of a “healthy” soil. By using manures and organic composts obtained through integrated crop and livestock farming, “healthy” productive soils could be developed and sustained. By contrast, the use of chemical fertilizers destroyed healthy soils, and people who consumed the nutrient-deficient crops produced on such soils suffered ill health (Harwood 1990).<sup>15</sup> More than two dozen books published during the 1940s and 1950s promoted the tenets and methods of organic (biological) farming.

These publications created a firestorm of controversy in agricultural circles, especially among urban gardeners,<sup>16</sup> and aroused the interest of editors of farm papers. In 1952, *The Progressive Farmer*<sup>17</sup> published a series of articles aiming to set the record straight on “This ‘Organic Farming’ Folly.” Citing research findings from several experiment stations, Eugene Butler (staff writer) argued (1) that both organic matter and chemical fertilizer are important in crop production (the two are not in conflict) and (2) that claims by organic farming advocates that chemical fertilizers were harmful to soils and human health betrayed a lack of knowledge of soil chemistry and ecology.

On the other side, the importance of the basic idea of plowing—inverting the soil—was challenged by Faulkner in *Plowman’s Folly* (1943). In this and other books, Faulkner argued that plowing controverted natural cycles of plant growth and decay, and that disking of cover crops to leave organic material on or near the soil surface provided an ecologically sound alternative that improved soil fertility and structure. Louis Bromfield’s widely read *Pleasant Valley* (1946) bolstered Faulkner’s claim that disking of green manure crops was a better technique than plowing in preparing plant beds as demonstrated by the higher crop yields.

Faulkner’s claims added to the storm of controversy surrounding conventional tillage and soil-building practices. Hugh Hamilton Bennett—the leading public figure in conservation policy debates—called for abolition of the plow, a recommendation that was rebutted by articles in

*Harper's* and the *Farm Journal* (Nelson 1997). Farm papers called on the foremost authorities to resolve the cloud of doubt about conventional wisdom. *The Progressive Farmer*<sup>18</sup> in 1947 published an article by L. D. Bayer, Dean of Agriculture, N.C. State College, titled "Five-State Experiments Answer 'Plowman's Folly.'" Noting the confusion among farmers created by counterclaims that "the moldboard plow is his ruin . . . [and that he should] buy better plows and do a better job of plowing," Bayer argued that "*the type of agriculture that the plow made possible*" was the problem rather than plowing itself. He argued that many farmers plow too much because they were not practicing a good "soil building rotation" and were sometimes plowing when only "a shallow surface seed bed preparation" was needed. He pointed out that good crops of wheat could be raised in Nebraska by cultivating instead of plowing, but that the highest yields of corn crops in Iowa and Ohio were on plowed ground, and in Virginia and North Carolina on sod ground. Clayey soils and deep-rooted legume sods needed to be plowed to give best results, especially with corn. However, with lighter, loamy soils, and/or shallow-rooted cover crops, plowing was not necessary and not necessarily best for the production of small grain crops. Farm readers, who hoped for an unambiguous endorsement of plow culture, were clearly disappointed. Tillage management was becoming more complex; the most appropriate system depended on the type of soil and crop.

Although advocates of organic farming and of alternatives to plowing overreached their grasp of both the science and the arts of farming, they had two notable impacts on farmers' understanding of agriculture. One was the expansion and deepening of the concept of soils as a living system, including the biochemical, bacteriological, and biological processes heretofore poorly recognized. Secondly, in contrast with the concept of water and erosion control as the central focus of soil conservation, the concept of soil management was gaining ascendancy.

From a soil management perspective, techniques of minimum tillage and stubble management were arrayed alongside of liming, fertilizing, rotations, cover crops, contouring, and terracing as resource conserving and development strategies of good farmers. From the 1920s onward, editors of *The Progressive Farmer* began promoting the use of lime, fertilizer, and cover crops for hay and plowed under in rotation, as well as terracing and contouring, as the standard of good farming practice in the southeastern United States. After World War II, the paper often featured master farmers who had successfully built up their farms through such practices.

By contrast, in the Midwest where soils were deeper, *Wallaces Farmer* and *Iowa Homestead* continued to emphasize until the 1970s the use of

engineering approaches—terracing, contouring, and strip cropping—for conservation.

By the mid-1950s, seed drills, which were developed to plant small grain in stubble mulch, were found to be effective in fertilizing and planting legumes, perennial grasses, and small grains in pasture sods.<sup>19</sup> The savings in labor and machinery costs in renovating pastures by direct drilling over plowing, cultivating, and reseeding were considerable. But, efforts to transfer the technology to row crops ran into numerous difficulties. Leaving corn stalks, soybean, or small grain residues on the surface resulted in planting delays, poor plant emergence, lower yields, and weed control problems (Buchele 1967; McCalla and Army 1960). Both the agricultural professionals and leading farmers in the fertile and economically prosperous Midwest continued to recommend plowing as the necessary and best first step in plant bed preparation.

As research information on the value of surface mulch mounted, however, various attempts were made to develop successful strategies for planting row crops (Buchele 1967; Nelson 1997). Researchers tried using subsurface tillers (Shedd and Norton 1943), plowing and planting in the untilled ground, or in the wheel tracks (Aldrich 1956), and till-planting on ridges (Buchele et al. 1955).<sup>20</sup> There were three minimum requirements. Crop yields had to equal, or nearly so, those on conventionally tilled ground. The tillage method had to be doable with present, or with modified present farm equipment, including tractors. And, it had to be timely; that is, it could not be the cause of delays in planting because yields and/or the acreage planted would be adversely affected.

These experiment-station efforts attracted the attention of farmers, and a few were sufficiently interested to try to overcome the associated difficulties. Although ridge planting was the only one of these methods to survive farmers' evaluations (Buchele 1967), the publicity associated with these developments further eroded the notion that plowing to remove surface residue and clean cultivation was necessary for successful crop production.

The factors compelling farmers to consider alternatives to plowing and cultivation as the best method of plant bed preparation, however, were economic more than agronomic. Under pressure to reduce production costs, farmers after World War II were continually searching for ways to reduce field labor costs and improve soil structure. Reducing tillage was one strategy of accomplishing this. From the late 1940s onward, midwestern farm papers periodically reported farmers' attempts to reduce labor costs and soil compaction by reducing tillage operations.<sup>21</sup> By the mid-1950s, farmers in Iowa and Illinois were exper-

imenting with several different methods. Under the heading "Short Cuts for Corn Tillage," *Wallaces Farmer*<sup>22</sup> stated that "Most soil experts agree that Corn Belt farmers work their soil too much," and indicated four methods of reducing tillage: listing, ridge planting, mulch tillage, and minimum tillage (wheel track planting). Although corn yields sometimes were lower than on conventionally prepared fields, farmers were interested, the columnist claimed, because of (1) time and cost savings, (2) less soil packing, (3) better water infiltration, (4) less erosion on contoured slopes, and (5) reduced weed growth in rough soil between rows. The principle that plowing was the most cost-effective first step in plant bed preparation for corn and soybeans had been bridged. The related principle that plowing and cultivation were necessary for weed control was the sole remaining technical pillar of plow culture, and it too was rapidly losing preeminence.

The necessity of plowing and cultivation for weed control was not so much toppled as undermined. It was a gradual process that took several decades. It began in the early decades of this century with the discovery in the laboratory of hormones and growth regulators of plants. The idea of using synthesized plant regulators to control weeds, however, did not occur until 1942 (Peterson 1967). As Shear (1985, 3) reports, "a new era in weed control started in 1942 . . . [with research] at Boyce Thompson Institute . . . on the formative effects of synthetic organic growth substances on plants." This research led to the discovery of 2,4-D,<sup>23</sup> which E. J. Kraus and J. W. Mitchell at the University of Chicago proved to be effective in controlling a wide range of broadleaf weeds (Peterson 1967). Due to wartime security regulations, studies of the herbicidal action of the newly discovered organic compounds on common weeds—bindweed and dandelion—were not published until 1944. A year later, the American Chemical Paint Company sought a "use" patent and marketed the first systemic herbicide with 2,4-D (Peterson 1967). Researchers at state agricultural experiment stations immediately began extensive field trials of the herbicide. From that point, the search for other equally potent growth inhibitors expanded rapidly.<sup>24</sup>

Word of a radically different method of controlling weeds exploded on the farm scene. Under the headline "Trying New Kind of Weed Killer," *Wallaces Farmer*<sup>25</sup> in March 1945 reported Hammer and Tukey's experiments with 2,4-D on weeds at the New York State Experiment Station and research by USDA at Beltsville, Maryland. Later that year under the heading "New Weed Sprays," farm readers of *Wallaces Farmer*<sup>26</sup> were informed: "Hormone weed sprays have reawakened interest in killing of lawn and farm weeds with chemicals" and that "E. P. Sylwester, Iowa State College . . . estimates the cost . . . at \$4 or \$5 per acre, and the cost

may get lower.” This was substantially higher, however, than the estimated cost of conventional cultivation.

However, shock waves rippled through the corn belt a year later with a *Wallaces Farmer* headline; “Kill Weeds in Corn with 2,4-D.”<sup>27</sup> It described successful experiments in killing Canada thistles and creeping jennie. This was followed in subsequent issues by reports from other locations of the successful use of the herbicide in cornfields. With this announcement, the possibility of using 2,4-D to help control weeds in the Midwest’s principal cash crop became a present reality.

The next stage in which 2,4-D became an alternative to cultivation as a method of weed control, at least in emergencies, soon followed. Through the pages of *Wallaces Farmer* and *The Progressive Farmer*<sup>28</sup> mid-western and southern farmers learned of the notable success of several farmers in Henderson County, Kentucky, in using 2,4-D to control weeds in corn during the 1947 crop year. In June of that year, just after most corn had been planted, the season turned extremely wet and on some Ohio River bottomlands farmers were unable to cultivate weeds in their cornfields. One farmer, however, had seen herbicide trials by his Extension Agent the previous year and, rather than abandon his crop, decided to try spraying twenty acres with 2,4-D. The results were spectacular. Eventually, the early weeds were killed in more than 14,000 acres of bottomland at a reported cost of only \$1.25 to \$1.50 per acre. Although costs averaged somewhat higher than for cultivation,<sup>29</sup> it was timely, and the crop was saved. Yields were reportedly higher than in fields where weeds were only cultivated.

From then on, the difficulties and limitations as well as the successes in the application of 2,4-D and other herbicides were regularly reported in the pages of farm papers.<sup>30</sup> Despite difficulty in obtaining satisfactory sprayers, farmers responded rapidly to the opportunity. A *Wallaces Farmer*<sup>31</sup> poll of Iowa homesteads indicated that 39 percent planned to use 2,4-D in their cornfields in 1954.

2,4-D was a remarkable herbicide in many respects. In addition to controlling many noxious weeds in lawns and pastures, 2,4-D controlled a wide range of broadleaf weeds in corn and cotton when applied either as a preemergent or contact herbicide. Used as a contact herbicide, it effectively controlled many weeds in rice and small grain crops. But, 2,4-D was harmful when sprayed on very young corn and had to be applied below the growth point; it did not control grasses and could not be used as a preemergent herbicide with soybeans. Moreover, it was soon discovered that grassy weeds, such as Johnsongrass and giant foxtail, which were not controlled by 2,4-D, began to flourish in unplowed fields when competition from other weeds were removed. Nevertheless, the

use of herbicides, especially preemergent herbicides, continued to expand. *Wallaces Farmer* reported that 67 percent of Iowa farmers in 1959 planned to use chemicals to some extent in their cornfields.<sup>32</sup>

Although most farmers continued to use herbicides as an alternative to cultivation in emergencies, by the end of the decade some farmers had progressed to the next stage in using chemical weed control as a regular part of their tillage strategy. That is, they regularly used herbicide sprays to replace one, sometimes two, cultivations of corn. But, the limitations—costs and difficulty controlling grassy weeds—meant that nearly all farmers continued to plow and prepare a “good plant bed” and cultivate once or twice.<sup>33</sup>

In 1948, *The Progressive Farmer*<sup>34</sup> had reported a successful experiment in raising corn without cultivation, but much developmental work remained. Not until simazine and atrazine became available in 1956 and 1958, respectively, did farmers have preemergent herbicides that effectively controlled many grassy and broadleaf weeds. It was another 10 years therefore before a few farmers were ready to seriously attempt such a radical tillage strategy. As the end of the 1950s neared, however, plow culture was no longer the unchallenged tillage system among American grain farmers. Doubt had been cast on its ruling principles, and alternatives to its technical procedures were being explored. On the plains, increasing numbers of farmers were practicing stubble mulching. Corn belt farmers who wanted to reduce tillage operations could substitute the application of herbicides or try one of several planting alternatives—listing, wheel track, or plow-plant.<sup>35</sup> But, the organization of these components into reliable and profitable tillage systems was far from complete, especially in the corn belt.

In this broad farming area, farmers still wrestled with many problems in using herbicides, including grassy weeds, perennial weeds, weed succession, and insects and diseases, especially when grass sod was not plowed and crop residues were left on the surface over winter. Herbicides as well as the new insecticides that were becoming available were highly toxic, and most farmers either were afraid to use them or did so only as a last resort. Farmers were only beginning to learn what the fertilization requirements were with different minimum tillage regimes. A satisfactory row-crop planter that could plant satisfactorily in various plant residues still was not available commercially.

Consequently, except for an occasional boom sprayer, the casual observer of the countryside in 1959 would hardly have noticed any change in the prevailing tillage practices. The typical farm scene still contained a farmer behind the wheel of a large tractor pulling a plow, disc, or harrow, or tracing evenly spaced rows in a cleanly cultivated

field. Custom had been bolstered by “scientific” evidence that fall plowing, especially when phosphate and potash were plowed under, produced larger yields of corn.<sup>36</sup> To increase productivity, farmers were buying more inputs, especially fertilizer and lime and larger tractors with which to pull larger plows and planters and farm larger acreages. Advertisements for tractors in farm papers invariably portrayed their power by showing the tractor pulling a four-bottom plow.<sup>37</sup> Each year at the Iowa State Fair, new champions were crowned at the National Plowing Contest. Plow-cultivate technology in the Midwest, although challenged, was still king.

### Australia

As the nineteenth century drew to a close, the pioneering ideology began to change to the rational assessment of natural resources for their economic benefits (Dovers 1992). The Australian government increasingly designed policies to foster resource development. Australian agriculture was then, and still is, dominated by export markets for wool, livestock products, and wheat. Wool and wheat marketing boards were established to help producers meet the demands of international market competition.

World War II left rural industries in an impoverished state because they had labored to meet wartime demands without many of the necessary inputs. Once the war was over, however, and chemicals and machinery once again became available, rural industries expanded rapidly. Wool producers in particular responded quickly to higher wool prices during World War II and the Korean conflict with the result that by 1952 the value of wool production represented 51 percent of all rural production. Grain growing, which had increased gradually in nearly all areas of Australia during the second half of the nineteenth century, expanded with particular rapidity after each of the world wars. Market booms and war service settlement policies for returning soldiers were largely responsible for this growth (Pratley and Rowell 1987; Gruen 1990; Campbell and Dumsday 1990). Many World War I veterans were rewarded with relatively small properties, and where rainfall permitted, they began raising wheat.<sup>38</sup>

During the 1950s and 1960s, moreover, the structure of Australian agriculture changed substantially as a result of the Commonwealth government’s policy objective of intensifying agricultural production in order to increase exports (Gruen 1990). To this end, the government acquired many large grazing properties, which it subdivided and sold or



leased to returned veterans. Faced with making a living on relatively small properties, farmers had to develop the land resource. Established tax and agricultural import policies also favored increasing farm capital. As in the United States, the intensification of production and expansion of cropping were facilitated by rationalization of farm management (Dovers 1992). Accordingly, scrub lands were cleared, and, where environmental conditions permitted, most farmers developed either wheat and sheep farms or shifted entirely to grain growing. Only the shortages of farm chemicals and machinery slowed the pace of the movement to intensive production (Gruen 1990).

With favorable prices during the Korean War, agricultural output increased dramatically, and farm incomes likewise. But, when wartime demand slackened, prices for farm products declined. With pressure on farm incomes and a progressive rise in nonfarm wage rates, real nonfarm family incomes were rising while farm incomes in real terms were declining. Farm youth responded by moving to the cities in search of employment. Between 1947 and 1961, the number of males in the farm workforce declined by 10 percent (Schapper 1967, table 9.1), and the percentage of the total Australian workforce in primary industries (except mining) declined from over 15 percent to under 11 percent (Shaw 1967). Farm labor wage rates thus were forced upward.

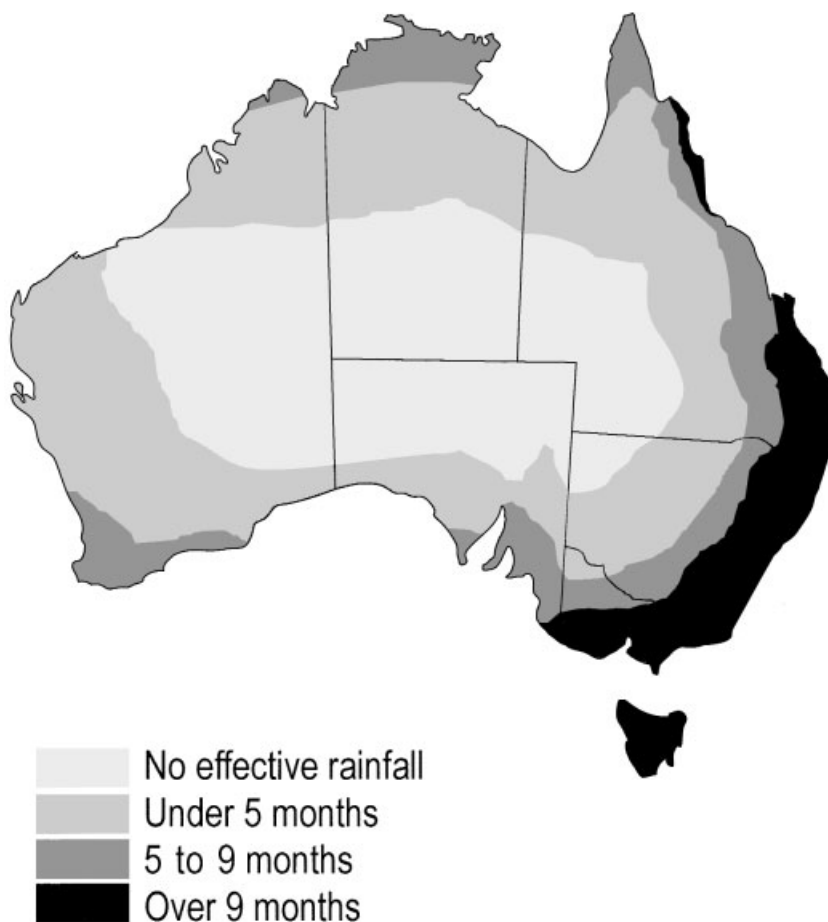
With rising farm labor costs, the pressure on farm incomes compelled farmers to further increase productivity to sustain family incomes. As in the United States, therefore, Australian farmers during the 1950s and 1960s continued to intensify land use with predictable disastrous effects on the soil resource base.

Due primarily to rainfall variation, topography, and soils, dominant farming systems have evolved in broad areas of the subcontinent (fig. 4.2). Broad-acre cropping occurs primarily in a semicircular band running from south central Queensland, across New South Wales, into Victoria, across the southern tip of South Australia, and most of the southwestern part of West Australia (Ockwell 1990). The dominant farming systems in this broad band are cereals (wheat), sheep, and cotton crops.

Farming systems are governed by rainfall patterns and soil characteristics. Cereal growers in northern New South Wales and Queensland primarily depend on summer rains spawned by tropical cyclones, whereas growers further south primarily depend on rainfall derived from prevailing westerlies, which move north in winter. The wheat-sheep zone generally coincides with the geographic area of five to nine months of effective rainfall (Ockwell 1990).<sup>39</sup>



Figure 4.2. Effective rainfall in Australia. (Source: Ockwell 1990, figure 3.1)



#### *Darling Downs, Queensland: Study Area*

Located in southeastern Queensland, the Darling Downs is the northernmost end of the wheat-sheep zone. The Downs and its associated conservation area comprises approximately 10 million acres (4 million hectares). The area is about 125 miles (200 kilometers) long and 20 to 25 miles (30 to 40 kilometers) wide and runs northwesterly from the border with New South Wales and with the Great Dividing Range as its eastern and northern boundaries. The rounded hills and broad valleys

along the dividing range gradually taper into rolling plains. The soils are primarily basaltic, self-mulching clays (Skinner et al. 1977).

Rainfall along the dividing range, two-thirds of which falls during the summer months, averages 26 to 28 inches annually (Beckmann et al. 1977). The average declines to under 20 inches within 200 miles west of the dividing range. Moreover, there is a 20 percent average variability in annual rainfall on the Downs (Davidson 1967), meaning that on average the annual rainfall varies between 21 and 33 inches. Cropping patterns on the Downs are determined as much by the rainfall variability as by the relatively low average.

During this century, and especially since World War II, grain growing has become more important. Cropland acreage on the Downs doubled between 1910 and 1940. After the Korean War, wool—the principal pastoral commodity—came under increasing price competition from synthetic fibers. Between 1952 and 1969, wool prices relative to prices of both wheat and beef declined (Johnson et al. 1990). Farmers on the Darling Downs responded by plowing their pastures and doubling the area of grain growing to about 2.5 million acres (1 million hectares). Except for those specialized in dairying, most farmers had some combination of beef cattle and/or sheep and summer and winter crops. Grain sorghum, sunflowers for oil, maize, and millet were the principal summer crops. Winter crops of wheat, barley, or oats for livestock forage sprouted and grew on the moisture stored during a summer fallow.

The common tillage system was “to burn winter crop stubbles as soon as possible after harvest and to prepare the land for another winter crop. Emphasis was directed at the conservation of rainfall in the soil through the control of weeds and the maintenance of a fine surface soil tilth” (Wilson 1978, 29). When sufficient moisture was available, farmers rotated cropping patterns by double cropping if plant bed preparation could be managed. Otherwise, rotation from summer to winter crops, or vice versa, required a “long (15 month) fallow.”

Because the heaviest rainfall often occurs in conjunction with cyclonic summer storms, these events coincide with the fallow period for winter cereal crops and the period when fields are developed in the finest tilth for planting summer crops. The severe erosion that occurred as cropland expanded after each of the two world wars prompted recommendations by authorities for changes in prevailing tillage practices.

### *Soil Conservation Policy and Practice*

Public concern with land degradation was initially aroused by Australia's version of the dust bowl in the 1930s, soil erosion in the catchments of major dams, and the deterioration in vegetation from overgrazing in the

arid pastoral zone. Unlike the United States, however, corrective action was regarded as a state, rather than a national, responsibility. States differed in their concerns, and Queenslanders were relatively slow to establish policies for addressing its erosion problems and relied heavily on other states for ideas and approaches.<sup>40</sup> Except for Queensland, "most of the Australian States established agencies concerned with the promotion of soil conservation" (Campbell and Dumsday 1990, 169) between 1938 and the end of World War II.

Erosion of the light Mallee soils in South Australia was particularly severe and initially attracted the most research attention. By 1940, research had demonstrated the value of maintaining a surface mulch in stabilizing these soils. The recommended soil conservation strategy for cereal growers was either to broadcast seed into stubble and cover by double discing, or to sow into stubble "using a seedbox mounted on a twin-disc plough" (Pratley and Rowell 1987, 12). Cover crops during summer fallow periods were also advocated. A gradual shift from a long fallow (15 months), during which weeds were controlled by cultivation, to a shorter fallow of 8 to 11 months also tended to reduce exposure of unprotected soils to erosion.

In Queensland, governmental conservation policy developed relatively slowly. The Bureau of Investigation did not appoint a Soil Conservation Officer until 1945. His surveys "identified the Darling Downs as an area requiring the most urgent treatment," and bolstered by growing numbers of concerned landholders, his initiatives eventually "led to the formation of the present [Queensland] soil conservation service" (Pauli 1978, 112).

The initial policy on soil conservation was set forth in *The Soil Conservation Act of 1951*. It established the functions of an Advisory and Coordinating Committee on Soil Conservation and the soil conservation role of the then Department of Agriculture and Stock (Pauli 1978). The legislation provided for local authorities to establish conservation projects. But, there was no provision for landholder participation in these projects (Stephens 1982).

Not until 1961, however, was the need recognized for a special organization to manage and conduct soil conservation work. In that year, "a Soil Conservation Branch was created in the Department of Agriculture and Stock" (Pauli 1978, 113). The small group of soil conservation officers had the mandate to investigate erosion problems, establish soil conservation areas, and provide guidance and training on soil conservation to agricultural and horticultural field advisory officers. Unfortunately, the press of the first two responsibilities did not allow time for the train-

ing function. Moreover, although the 1951 Act authorized erosion control “projects,” different bodies were responsible for planning and administration of the projects, which contributed to the ineffectiveness of the program.

Due to its inherent weaknesses, the 1951 act was repealed and replaced by *The Soil Conservation Act* of 1965. Under provisions of the 1965 act, landholders were empowered to form “Trusts” for the purpose of administering “soil conservation activity within defined Districts” (Stephens 1982). The Soil Conservation Authority (SCA) was also empowered to establish and administer conservation schemes in small project areas. SCA also could recommend to the Governor of Queensland in Council that particular areas be declared Areas of Erosion Hazard. Subsequently, landholders could be given cash incentives to carry out erosion control works under the direction of SCA officers.

Although landholders in particularly vulnerable locations began to plant grass strips and develop terraces, generally they did not rush to take advantage of the opportunity to assume leadership of area erosion-control projects through formation of Soil Conservation Trusts (Stephens 1982). More satisfactory collective erosion control measures were eventually mounted through governmental declaration that certain land areas were Areas of Erosion Hazard. Eleven Shires on the Darling Downs was the first area to be so designated in 1973.

### *Water Management and New Tillage Techniques*

In Queensland, the first experimental studies in water management using contour banks (terraces) had been made on the Darling Downs in 1935. South Australian studies on stubble retention and erosion also were known. By 1950, soil conservation officers began to modify conventional recommendations on cultivation and to encourage retention of surface mulch as long as possible by delaying plant bed preparation for winter crops until after the rainy season, and to recommend strip cropping, the construction of contour banks, and contour planting (Skinner et al. 1977).<sup>41</sup> Chisel plows were introduced on the Downs in the 1950s, and one distributor had sold 400 by 1956.

But, plowing with the Sundercut and cultivation to control weeds, which quickly buried the available stubble, remained the prevailing practice. Moreover, when the residue from harvest was heavy, the burning of straw was a common practice.

Another innovation that gained acceptance in winter rainfall in wheat-growing areas was “the introduction of subterranean clover and barrel medics in the crop rotations” and the elimination of bare fallow

(Dumsday et al. 1990, 180). But, in the summer rainfall areas of northern New South Wales and Queensland, this practice did not take hold.

News of the new phenoxy herbicides (e.g., 2,4-D) reached Australian farmers in 1947 and soon proved to be an economic method of controlling broadleaf weeds (Pratley and Rowell 1987). Wheat growers, who were suffering economic losses from wild mustard, skeleton weed, wild turnip, hoary cress, and saffron thistle, began using herbicide weed control. This changed the weed spectrum from broadleaf to grassy weeds (e.g., wild oats and annual rye grass). Attempts during the 1950s to use arsenical compounds to control weeds in fallow, however, were abandoned because of the long residual activity of the herbicide. Thus, cultivation remained the prevailing fallow weed control practice during the fifties.

### Summary

In the United States after World War II, continued parity price, subsidized credit policies, and expanded world markets and agricultural research and development coupled with rising labor costs spurred both intensification and specialization of agricultural production. As grain growing increased under plow culture, the land exposed to the risk of erosion increased accordingly. This stimulated governmental policies and social movements to adopt soil-conserving practices. Some policies (e.g., Soil Bank and productivity-enhancing conservation practices), however, tended to be self-defeating. Meanwhile, technological developments in the use of chemical herbicides coupled with pressure to reduce field costs induced farmers to consider substituting chemical weed control for cultivation, and stimulated research on new tillage systems. Stubble mulch tillage, which farmers in plains states began to adopt in the 1950s, presaged even greater innovation in the 1960s, initiating development of a new culture of agriculture.

As in the United States, the 1950s found Australian farmers beset by economic pressures to increase productivity and utilize their soil resource base as fully as possible. Farming systems had become relatively stable and linked to the local ecology. Grain grower concern with erosion impelled some to begin to change tillage practices and crop rotation strategies to reduce soil erosion. Farmers were beginning to use chisel plows, build contour banks, and avoid burning the stubble. These changes and the experience gained in using herbicides to control weeds in grain crops foreshadowed substantial change in tillage systems during the following decade.

## Notes

1. Indicative of the growth in agricultural research, public research funding, which was growing at a compound rate of 4.2 percent per annum in constant dollars, expanded from \$521.6 million in 1950 to \$797.9 million in 1960 and to \$1,023.8 million in 1970 (Huffman and Evenson 1993, table 4.1). Meanwhile, private research expenditures grew from \$346.3 million in 1945 to \$890.6 million in 1956 and to \$1,486.0 in 1970. Total research staffs in State Agricultural Experiment Stations nearly tripled during this period: 1940, 4,177; 1950, 6,363; 1960, 9,607; and 1970, 11,771 (Huffman and Evenson 1993, table 3.2). The qualitative improvement was also substantial as the percentage of PhDs increased from 46.4 percent in 1940 to 72.4 percent in 1970.

Funding for cooperative extension also increased rapidly. The total federal, state, and local funding for extension, which in 1950 was \$73.4 million, had by 1960 grown to \$140.1 million, and in 1970 to \$290.7 million in current dollars (Huffman and Evenson 1993, table A4.3). During this period, real growth in funding for cooperative extension increased at a long-term compound rate of 2.9 percent per annum.

2. By 1955, the value of farm real estate per farm worker in the United States was four times larger than in 1940 (Brake 1972, table 8.2).

3. From 1940 to 1950, the price of labor increased 229 percent compared to a 103 percent increase in the price of land. During the 1950s, the price of labor increased 130 percent compared to a 90 percent increase for land (Schertz 1979, figure 18).

4. In reviewing "Farming in the Fifties" for *The Progressive Farmer* (Vol. 75, No. 2, February 1960, p. 39), Bill Barksdale reported that corn growers had increased yields by 35 percent.

5. "Fertilizer use has increased more than fivefold since 1950 . . . [and] the horsepower incorporated in . . . tractors has increased almost 150 percent" (Schertz 1979a, 27).

6. The Kentucky Cooperative Extension Service, as many other states during the 1950s, developed educational programs in farm and home management, and began establishing regional management groups of farmers who kept records of farm costs, production, prices received, etc., and received annual reports of relative enterprise profitability.

7. Between 1954 and 1964, the percentage of cash-grain farms with chickens declined from 66 percent to 29 percent, with hogs and pigs from 41 percent to 28 percent, and with cattle and calves from 74 percent to 58 percent (White and Irwin 1972, table 11.2). This has been a long-term trend as Hornbaker and Denault (1993, 105) concluded that "all of the [north central] states have exhibited a disinvestment in livestock diversification" during the 1980s.

8. From the early decades of this century, the leading farm papers, such as *The Prairie Farmer*, *The Progressive Farmer*, and *Wallaces Farmer and Iowa Homestead*, devoted substantial attention to the costs of soil erosion and ways of reducing it through the use of cover crops and terraces. In 1928, B. W. Kilgore, editor of *The*

*Progressive Farmer* (Vol. 43, No. 42), reported an estimate that “not less than 10,000,000 acres of formerly cultivated land have been permanently destroyed in this country from washing” and according to North Carolina tests that “only 50 years would be required to wash away seven inches of soil from an unprotected cotton field” or 73 years to lose an equal amount from a corn field. He went on to note that “[w]hile erosion increased with the intensity of rainfall the controlling influence was cultivation” and emphasized the importance of using cover crops and “broad based terraces.”

9. From the 1920s through the 1960s, farm papers regularly featured articles on the benefits of terracing and the best ways of constructing them. For example, *The Progressive Farmer* (Vol. 44, No. 8, p. 10) in 1929 carried a full-page editorial dealing with “How We Can Stop Washing,” “Essentials of Broadbase Terrace,” “Laying Off the Terrace,” and “Building the Terrace.”

10. On July 12, 1930, *The Progressive Farmer* (Vol. 45, No. 28, p. 4) editorialized on the “Money angle of soil conservation” citing H. H. Bennett’s, Bureau of Chemistry and Soils, statement that a flood on the Rio Grande “carried soil sufficient to build an earth tower one acre in area at the base and eight miles high.” The editorial further estimated that cotton crops on eroded land earned \$18.50 per acre less than on noneroded land.

11. Reflecting the interagency conflict and official efforts to present a united front, *The Progressive Farmer* in 1952 (Vol. 69, No. 11, pp. 54, 58) reported an interview with Extension Service Administrator Clarence Ferguson and Soil Conservation Service Administrator Don Williams, which focused on allegations of conflict (e.g., that extension and land-grant colleges were planning to take over the soil conservation job, were dragging their feet in establishing Soil Conservation Districts, or were seeking to substitute farm management planning for farm conservation plans, and the like).

12. From the 1920s through the mid-1950s when federal conservation programs shifted from soil-saving practices to placing erosion prone land in conservation reserve, farm papers regularly contained editorials and articles on the economic benefits of conservation practices, the practices themselves, and the machinery to use. For attention to these issues by *The Progressive Farmer* in the post-World War II period, see “Building Soils Is Paying Off South’s Farmers” (Vol. 62, No. 6, June 1947, pp. 15, 28), “New Styles in Soil Saving” (Vol. 64, No. 3, March 1948, pp. 19, 26), or “Operation Gully Plugging” (Vol. 68, No. 2, February 1953, p. 21). *The Progressive Farmer* also annually featured “Master Farmers” who invariably used good soil-building and conserving practices (e.g., “Just Learning to Farm” [Vol. 64, No. 2, February 1949, p. 13]). In *Wallaces Farmer and Iowa Homestead*, for example, see “Hill Farmers Learn to Save Soil: AAA-SCS Program Helps Southwest Iowa Make Money with Conservation Methods” (Vol. 71, July 20, 1946, p. 663), “Good Land Use Pays” (Vol. 73, May 1, 1948, p. 8), “Terraces Hold Soil, Water, and Fertility” (Vol. 73, September 4, 1948, p. 30), or “Conservation Pays” (Vol. 76, March 17, 1951, p. 83).

13. The latter complemented the “acreage reserve” program in the farm bill, which paid farmers to reduce acreages of supported crops below allotment levels and put diverted acres to conservation uses (Rasmussen 1982).



14. This instrument featured a V-shaped share mounted on a goose-necked frame and attached to wheels. When operating, the share traveled from 2 to 4 inches under the surface, loosening the soil and disturbing weeds, but leaving crop residue on the surface.

15. The conservation organization Friends of the Land, which was organized in 1940 by Hugh H. Bennett, Aldo Leopold, Russell Lord, Louis Bromfield, and others, promoted the idea “that a healthy soil was the basis of a healthy society” (Nelson 1997, 77).

16. A 1952 article appearing in *The Progressive Farmer* (Vol. 67, No. 3, p. 74) claimed that “[c]olleges of agriculture in many states have been swamped with letters from people alarmed by the claims appearing in the widely distributed ‘organic farming’ literature,” and that “[u]sually it is the city man, a gardener with only back yard experience, who is bitten by the ‘organic farming bug.’ ”

17. Vol. 67, Nos. 3, 5, and 6.

18. Vol. 62, No. 10, pp. 15, 109.

19. The use of “sod drills” to renovate pastures was featured in a 1954 article “New Tools Rebuild Pastures” in *The Progressive Farmer* (Vol. 69, No. 8, p. 26).

20. In 1946, *Wallaces Farmer and Iowa Homestead* (Vol 71, April 20, p. 376) under the title “Grow Corn without Plowing” reported a 2-year experiment at Iowa State Experiment Station comparing corn yields in fourteen counties with plowing and conventional tillage, listing, and discing and subsurface tillage. Although in western Iowa corn yields were the same for all three methods, in central Iowa corn planted with conventional tillage or by listing had the best yields, and in northeast and southcentral Iowa, conventionally planted corn had the best yields.

21. In 1948, under the heading “Cut Corn Field Labor” *Wallaces Farmer* (Vol. 73, April 3, pp. 8, 384) reported that compared with plowing, listing corn in untilled fields reduced labor by 50 percent, discing alone by 16 percent, and subsurface tillage by 25 percent. Yields equalled those on plowed ground. In 1954, a till-plant experiment was reported by *Wallaces Farmer* (Vol. 79, November 20, p. 12) under the heading “Plant Corn with Less Work,” and in 1955, *Wallaces Farmer* (Vol. 80, May 21, p. 12) summarized the opinions of soil scientists and farmers on “Do Corn Belt Farmers Work Soil Too Much?” They argued that habits of cultivation with horse-drawn equipment were both unnecessary and harmful. “Extra time over the field with heavy machinery is hard on the soil. Ohio tests show that heavy machinery plugs soil pores, breaks down structure, slows aeration, and reduces root penetration.” Favorable outcomes on several Iowa farms with reduced tillage were cited.

22. Vol. 82, April 20, p. 24.

23. (2,4-Dichlorophenoxy) acetic acid.

24. “By 1962 companies marketed about 100 herbicides in 6,000 different formulations” (Peterson 1967, 252).

25. Vol. 70, March 17, p. 230. 2,4-D, the article says, “induces unnatural growth responses in plants” leading to their death. “Favorable results with the weed killer have also been reported from the U.S.D.A. experiment station at Beltsville, MD” with dandelion and plantain.



26. Vol. 70, November 17, p. 853. Other farm papers were not far behind in informing their readers of the event. Readers of the February 16, 1946, issue of *The Prairie Farmer* (Vol. 118, p. 12) were informed about the new weed killer in the article "New Chemical Kills Weeds in Lawns but Doesn't Hurt Grass." In a March 1946 article on "2,4-D, New Killer for Weeds," L. W. Kephart, USDA, wrote in *Successful Farming* (Vol. 44, pp. 28, 48, 49) that studies now indicated "2,4-D is *definitely* a good thing on lawns, *probably* a good thing to use on pastures, is still *questionable* on corn and small grains, and is least promising, possibly in combination with tillage and cropping on a considerable number of the bad perennial weeds."

27. Vol. 72, May 3, 1947, p. 530. "In 1945 and again in 1946, [Iowa State botanists used 2,4-D on] Canada thistles and creeping jennie" and obtained a 70 percent kill after two sprayings the first year and 90 percent the second year; also killed were smart weeds in oats.

28. Vol. 62, No. 12, December 1947, pp. 13, 83–84, 101. Joe King, one of the farmers trying 2,4-D, is quoted: "I think we are witnesses of the greatest agricultural development for this area since the coming of the tractor and power farming. I believe it may cut our cost of corn production by one-third."

Farm readers of *Wallaces Farmer* on August 16, 1947 (Vol. 72, p. 804) were informed of the successful use of 2,4-D on these cornfields, where it was noted that one of the "Agricultural college men who inspected the fields . . . expressed the opinion . . . that these experiments 'may be the birthday of a revolution in agriculture.'"

29. In 1959, comparative per acre prices charged by custom operators in Kentucky were (1) cultivation of corn, \$1.00 to \$1.50 and (2) 2,4-D spray, \$1.50 to \$2.50 (material included) (Phillips 1959).

30. In 1950, *The Prairie Farmer* (Vol. 122, April 15, p. 6) sought to help farmers solve what had become an annual dilemma: "Which Spray Chemicals Shall I Buy?" "To Use on Insects," and "To Use on Weeds." For the latter, the choices then were 2,4-D, 2,4-T, TCA, Amate, and PMA.

31. Vol. 79, April 17, 1954, p. 6.

32. Vol. 84, April 4, 1959, p. 30.

33. Scientists in Iowa continued to recommend a package of practices (i.e., prepare good plant bed, use clean seed, use a preemergent herbicide, followed by one or two cultivations, then a contact herbicide as the lay-by application) as the best strategy for controlling weeds. See two articles in *Wallaces Farmer*: "Stop Weeds in Corn and Beans" (Vol. 83, May 17, 1958, p. 16) and "Control Weeds with Herbicides" (Vol. 84, April 4, 1959, p. 30). A similar strategy of weed control was recommended to southern farmers. See *The Progressive Farmer* ("Kill Weeds and Brush," Vol. 70, March 1955; Vol. 71, March 1956, p. 66).

34. Vol. 63, No. 10, October 1948, p. 18. W. C. Lassiter, under the headline "2,4-D The Weed Killer," showed pictures of weed-free corn grown on a University of Kentucky experiment station plot without any cultivation or hoeing. The story also reported a cotton field in Mississippi with no cultivation and half the usual hoeing as well as rice and corn crops saved from weed infestation by spraying. It also showed pictures of a front-mounted boom sprayer in chest-high corn.

35. Under the headline "Cut Expenses with Minimum Tillage," *Wallaces Farmer* (Vol. 84, March 7, 1959, p. 42) mentioned two Linn County farmers and one in Monona County who had satisfactory experiences in using these methods in 1958. The story also mentioned Purdue University studies that found a \$5 per acre cost saving of wheel-track planting over conventional planting.

36. *Wallaces Farmer* (Vol. 78, October 3, p. 18) reported that average corn yields over 11 years at Iowa State College were three to four bushels per acre higher on fall than spring plowed ground. In 1958, *Wallaces Farmer* (Vol. 83, March 15) reported that "[f]ertilizer experts generally agree that extra phosphate and potash should be plowed down."

37. For example, *The Progressive Farmer* (Vol. 72, No. 4, April 1957, p. 84) featured "The March of Machinery" showing International Harvester and John Deere four-row planters. The following year (*The Progressive Farmer*, Vol. 73, No. 2, February 1958, p. 60), "New Farm Equipment 1958" displayed a new McCormick 650 six-row planter and Ford's new 44 drawbar four-plow tractor.

38. Pratley and Rowell (1987, 9) point out that in Queensland and northern New South Wales at this time, cropping "spread rapidly westward into grazing lands, and soil erosion became a major problem."

39. Effective rainfall is the amount of rainfall necessary for growing crops considering prevailing temperatures and soil porosity, which control rates of evaporation and evapotranspiration (Ockwell 1990).

40. For brief histories of the early development of soil conservation problems and policies in each state, see *Journal of the Soil Conservation Service of N.S.W.* (Vol. 34, No. 2, April 1978).

41. "Amended practices considered necessary included the following:

1. Conservation of all crop residues as a protective surface mulch.
2. Delay of the first ploughing after harvest at least until after closure of soil cracks by wetting and swelling.
3. Deeper initial ploughing.
4. Retention of the soil in a cloddy condition for as long as possible after harvest.
5. Reduction of the number of tillage operations sufficient only for weed control.
6. Fire harrowing, if necessary, to destroy undecomposed crop residue at the end of the rainy season (necessary to permit the use of combines).
7. Delayed preparation of a seedbed until after the wet season.
8. Contour cultivation in conjunction with contour banks." (Skinner et al. 1977, Appendix I)

# 5

## The Social Construction of Innovative Networks

*Retrospectively, one can argue that a third fluorescent lamp was designed—not on the drawing board or at the laboratory bench but at the conference table. This artifact—the high-intensity daylight fluorescent lamp—came slowly into being during the meeting.*

—Bijker (1992, 88–89)

Starting in the 1950s in the United States and the 1960s in Australia, a new “adaptive nexus” for farming was created by changes in governmental policies, developments in technology, and the impact of plow culture on the environment. On the one hand, new ideas and techniques of weed control and soil management were being developed, which challenged the principles undergirding plow culture. At the same time, farmers found that farm policies and markets were providing incentives for adaptive changes in their farming systems as well as the resources for making changes. Imaginative scientists, farm advisors, and farmers responded to the new nexus of constraints and opportunities by constructing novel tillage and cropping systems.

A significant element in innovators’ abilities to construct these new tillage systems was their ability to find and gain the support of allies. These variously included agricultural scientists, local extension and soil conservation agents, machinery and chemical company representatives, and other like-minded farmers. The social construction of *local* and *global* networks, operating with a common technical frame and engaged in the elaboration and specification of the frame for specific tillage systems, was crucial to the eventual success of the innovative enterprise. The roles they played in formed networks, as different problems were addressed and different components of the technical frame put together, help answer questions as to the origin of successful no-tillage agriculture. The examination and analysis of these innovative support networks are the purposes of this chapter.

## Prior Research

The importance of farmers' involvement in social networks in the acceptance of new technology has been recognized for a long time. Indeed, the particular networks of communication (or influence) involving change agents, local innovators, and other farmers in the *diffusion of innovations* has been studied extensively (Rogers 1983). However, the typical assumption in these studies is that the innovation itself (e.g., hybrid seed or new machine) is fully developed and available for adoption by farmers. The main network function is to provide a channel of information and influence. Studies of the roles of farmers as collaborators with scientist-advisors in agricultural innovation have been largely limited to the adoption of innovative technologies in developing countries (e.g., Chambers et al. 1989; Ashby et al. 1996).

Although the role of innovative networks in the early adoption of no-tillage has not been a specific focus of prior research, the importance of farmers' relationships with extension and/or soil conservation agents, agricultural company dealers, and other farmers has been highlighted by several studies (Choi 1981; Nowak and Korsching 1983; Nowak 1987; Carlson and Dillman 1986; van Es et al. 1986). Indeed, these studies show that in the initial decision process, most farmers obtained information from multiple sources, including other farmers. And, farmers in Queensland, Australia indicated that extension and conservation agents were their most important sources of information on erosion control (Chamala et al. 1983). However, the relative significance of representatives of particular agencies has varied. Much of the difference in the role of institutional agents from one area to another seems due to which agency became involved first in developing no-till systems. But, there is much individual variation within areas. Who initiated the tillage innovation process—the farm advisor or the farmer? What prompted the consideration of tillage system innovation? What role did members of the network play in the innovation process? Was the flow of information one-way or two-way? These questions have mostly not been addressed by these studies.

Researchers interested in the relative speed of innovation adoption have focused on both the characteristics of farmers in communication networks and the density of the interconnections among them as explanatory factors. In fact, most networks are composed of farmers who live nearby and have similar socioeconomic characteristics (homophilious)—education, farm size, type of farm, income, and the like. Whereas information disseminates rapidly within a network of spatially close and homophilious individuals, information about innova-

tions tends to be constrained within the network due to its exclusiveness. In a community primarily composed of such networks (e.g., a community of multiple neighborhoods or ethnic groups), which are tightly knit, the flow of information throughout can be relatively slow. Thus, studies have tended to show that information flows most rapidly throughout farming communities or regions where the networks link farmers with dissimilar socioeconomic characteristics or when various homophilious groups are linked with each other by one or more members who are heterophilious.<sup>1</sup>

In studies of no-tillage adoption, "other farmers" are often mentioned as one of the sources of no-till information, which innovative farmers regard as "primary" (Carlson and Dillman 1986) or "best" (van Es et al. 1986). In a related study, Carlson and Dillman (1983) found that, compared with solo operators, kin operations—farming with a parent or a relative—were more innovative, especially in the adoption of erosion control techniques including minimum tillage and no-tillage practices. They speculate that this could be due to greater opportunity to interact with someone regarding the innovation, greater resources (and flexibility) associated with a larger farming operation, or a longer planning horizon and concern with maintaining soil productivity. However, a replication study of innovativeness among Illinois farmers (van Es and Tsoukalas 1987) did not find that a kinship tie was important in explaining innovativeness either of erosion control or nonerosion control practices. The lack of importance of a kin relationship to innovativeness is, they hypothesize, due to a different purpose in adopting erosion control practices by Illinois farmers (i.e., the prevention of off-site pollution, rather than of loss of future productivity, as in the Palouse; although why there is also no relationship of nonerosion control innovativeness, which does have productivity implications, to kinship tie is not clear).

What we would like to know, but previous studies have not revealed, is when the networks are formed in the innovative process, what functions do they serve? In the innovation phase, by contrast with the later stages of diffusion, inventors usually have more questions than valid information to dispense. Communication with others can be important, especially in determining the right questions and in designing appropriate experiments to provide the necessary information (Latour 1987; Bijker 1987, 1992). When an innovation has been fully developed and tested, the questions of potential users on the other hand turn to the innovation's technical requirements and its relative cost and performance benefits. Such information travels from media and change agents to networks of potential users—from early adopters and opinion leaders to later adopters (Rogers 1983).

Consequently, although the studies have indicated that contacts with other farmers have been important in decisions to try no-tilling or stubble mulching, the studies tell us very little about why these contacts have been important. That is, the studies have not provided information on (1) what kind(s) of helpful information on what kinds of issues was provided by these "other farmers," (2) when in the process of constructing their own tillage systems they obtained information and/or advice from other farmers, or (3) who they were (i.e., their socioeconomic resources), and (4) the roles played.

Another problem is that in previous diffusion studies, the communication network for a particular innovation was primarily considered to involve the farmer's existing social relationships. The network through which the innovation flowed was embedded, as it were, in the relationships among kin, neighboring friends, or social cliques (Lionberger et al. 1975; Rogers and Kincaid 1981; Granovetter 1973). In this case, formation of the communication linkages for a particular innovation is no more problematic than the discovery that a neighbor, friend, or kinsman has newsworthy information. The communication network is simply a function of (1) the structure of the underlying network of friends and acquaintances and (2) the level of a farmer's interest in a particular innovation.

Studies of the social construction of innovations, however, indicate that establishment of a network of individuals and/or groups to construct a particular innovation is a highly problematic activity. In developing bakelite (the forerunner of modern plastics), Baekeland became quite frustrated at the lack of interest in collaboration among fellow celluloid chemists and rubber manufacturers (Bijker 1987). Finally, he successfully enlisted the support of people in unrelated industries. Similarly, Callon (1987) emphasizes both the importance of, and the effort French engineers put into constructing, an "actor network" for development and manufacture of the VEL electric car. The local network consisted of a heterogeneous set of fuel and automobile manufacturers, and potential customers with convergent interests in energy efficient and environmentally safe automobiles. The convergence of interests was effected by means of the social construction by the network of a "technological frame" (Bijker 1987, 1992), which shaped the technology of the proposed car, and which in turn structured the actor network.

Expanding this concept of actor network, Law and Callon (1993) formulated the concepts of a "global" network with which the "local" (innovative) actor network interacts in the social construction of technology. The *global network* provides the essential financial, technical, and infor-

mational support for the innovative technological project. The global arena in which actor-network is constructed constitutes the “adaptive nexus” to which Bennett (1982) refers.<sup>2</sup> Global actors provide, in Law’s and Callon’s (1993) terms, the “negotiating space”—the time and resources—necessary for the local actor-network to construct a new technical system.

To summarize, we argue that through networking, innovators gain the support essential to the innovative process. The empowerment of innovativeness includes the provision of technical information about soils, chemicals, implements, advice on conducting experiments, and the like; the provision of financing, chemicals, and implements; and the establishment of a forum for discussing results of trials, and the development of a common technical language for the new tillage frame.

In this chapter, we analyze the construction of the heterogeneous local networks in Kentucky and on the Darling Downs of southeastern Queensland, Australia, that constructed technological frames of new tillage systems for innovative systems of farming. (See fig. 2.3.) We identify the different actors, characterize their roles, indicate the formation of the network historically, and provide an overview of the development of the technological frame. Because of the greater availability of data in the Australian case, greater attention is given to both the construction and activity of the local networks and their relationships to global supporters (i.e., agencies and institutions).

In the process, we highlight differences in the economic and policy environments of Kentucky and the Darling Downs, Queensland. These differences significantly impacted the development of the tillage and farming systems in the United States and Australia.

### **Innovative Networks in Kentucky**

The first operational no-tillage system was constructed by a local network centered in Christian County, Kentucky. The innovative network was not established at a single point in time but rather evolved as the key actor—Harry Young, Jr.—addressed different problems and drew others into participating in construction of what eventually became a no-tillage cropping frame. The principal actors in the emergent *local* network, in addition to Harry Young, Jr., and his operating partners (brother and father), were two other local farmers—E. G. Burks and E. C. Martin—as well as Reeves Davie (Christian County Agricultural Extension Agent), and Shirley Phillips (Extension Crops Specialist at the University of Kentucky).

*The Actors and Their Prior Experiences*

Harry Young, Jr., had been a farm management specialist with the Kentucky Cooperative Extension Service. But, in 1954 he resigned to partner with his father (Harry Young, Sr.) and brother (Lawrence Young) in operating the 1,235-acre family grain and livestock farm in Christian County. Harry Young, Jr., had been trained in agronomy as well as in agricultural economics. He was concerned with the problem of soil erosion and immediately set up a rotation of grain and forage crops to protect vulnerable fields. Of equal importance, in nine years with the Extension Service, he had become well acquainted with the extension information networks, had developed friendships with many of the extension specialists and county extension agents, and was knowledgeable about developments in soil, crop, and weed management.

In 1956, Reeves Davie replaced the local Agricultural Agent in Christian County. In his previous position as an agricultural agent in Carlisle County, Reeves Davie had worked with Harry Young, Jr., before the latter left the Extension Service. Moreover, as Carlisle County Agent, he had more than once visited the annual Experiment Station field day at Dixon Springs, Illinois. Like Harry, Reeves Davie had a background in agricultural economics and was interested in farm management and in improving farm productivity with use of the new technologies that were becoming available. It was a period of expansion in research and extension programs for agriculture.<sup>3</sup> Reeves Davie knew how to use farm leaders, such as Harry Young, Jr., in building an effective extension program, and the two quickly developed a good working relationship.

In the fall of 1956, due to the mutual interest in better farm management, Reeves Davie obtained Harry Young's help in organizing an extension course for fifteen farmers on record keeping and farm business analysis. In 1957, working through the Extension Service and with Reeves Davie, Harry Young led an effort to improve grain marketing in Christian County. It culminated in 1968 in the establishment of the Farmers Cooperative Grain Elevator in Hopkinsville and a complete marketing program for locally produced grain. From 1957 to 1970, during which time he worked with Reeves Davie in developing and promoting no-tillage and double-cropping systems, Harry Young, Jr., was at various times a 4-H Club leader, member of the County Extension Council, the Extension Board, the Crop Improvement Committee, and the Beef Show Committee.<sup>4</sup> To some extent, these activities reflect the attention generated by Young's experiments with no-tillage, which he started in 1961. But, these leadership positions, of course, also provided opportunities for wider contacts in Christian County and facilitated access to a wide range of information.



In 1953, the year before Harry Young left the Kentucky Cooperative Extension Service to start farming, the Service promoted one of its young county Associate Agricultural Agents—Shirley Phillips—to the position of State Agronomy Specialist. Mr. Phillips had grown up in central Kentucky, graduated in 1948 from the University of Kentucky with a degree in agricultural economics, and was hired by the Extension Service. To strengthen his qualification as an agronomy specialist, Shirley Phillips began and finished in 1956 a master's degree in agronomy with primary interest in crops. Field crops was an interesting area in which to work because of the continuing effort to improve productivity of major crops by reducing costs and raising yields through use of higher yielding varieties and proper application of fertilizer.<sup>5</sup> Shirley Phillips aimed to become the reigning expert in Kentucky on the production of commercial crops, especially corn and soybeans.

In connection with this focus, Phillips' attention was drawn to field trials in the use of chemicals to control weeds as well as to the research being conducted at several different research stations on planting crops using plow-plant or minimum tillage methods.<sup>6</sup> Several factors prompted this interest in reduced tillage. One was the erosiveness of Kentucky soils under cultivation; another was the economic pressure on farmers to plow land in fescue sod for greater return from cropping, and, third, to reduce tillage costs. Although chemical control was more expensive than cultivation, it was far less expensive than hoeing, which was the main method of killing weeds in corn rows.<sup>7</sup> Moreover, herbicides could control weeds in fields that were too wet to cultivate. While researchers at the Kentucky Agricultural Experiment Station conducted trials of new chemical weed killers, Phillips worked with farmers in field trials. He became an extension weed control specialist. The aim was to use herbicides to control weeds where cultivation could not do it, or do it as well, and to obtain the most effective control with the least amount of chemical. Spraying preemergent chemical in a footwide band over the row after planting and cultivating between rows kept chemical costs low while providing effective in-row weed control. Spraying 2,4-D at layby stage also suppressed late-season weeds.<sup>8</sup> In the late 1950s, this reduced-tillage strategy appealed to increasing numbers of farmers throughout the corn belt.<sup>9</sup>

In Harry Young, Jr., Shirley Phillips found a farmer cooperator who was also highly interested in crop production. In 1959 and 1960, Shirley Phillips arranged with Harry Young, Jr., to conduct official extension trials of sorghum varieties (Davie 1996). This collaboration continued for more than a decade. Harry Young cooperated in conducting official extension trials of soybean varieties and chemical weed control in corn and soybeans.

*Initial Networking and Framing Reduced Tillage*

Moreover, Harry Young was interested in trying innovative approaches to keep corn fields as free of weeds as possible. Dalapon had just been released and labeled for the control of annual and perennial grasses in corn. The wet spring of 1959 provided an opportunity to see if Dalapon could provide satisfactory weed control (van Es and Notier 1988). Satisfactory control of all weeds was not attained, however, and Harry Young did not repeat the trial. Shirley Phillips, as well as Reeves Davie, were interested observers of the failed attempt. It confirmed the experiences of other farmers in attempting to substitute chemical weed control for cultivation. But, Harry Young, Jr., did not give up the idea of controlling weeds with herbicides, and when a new and more effective preemergent herbicide—Atrazine—became available, he was ready to try it again.<sup>10</sup>

The reigning formula in 1960 for high corn yields was to plow in the fall, till a good seedbed in the spring, use adequate amounts of fertilizer, seed a high plant population before May 25, and control weeds and insects.<sup>11</sup> Shirley Phillips, and all agricultural extension agents, knew and advocated this formula (Phillips and Loeffel 1963; Phillips 1992). But, they also were aware of the mounting problems with the tillage aspects of this formula. Although fall plowing aided decomposition of green manures and saved time in the spring, it exposed the soil to greater erosion. Terraces and contours, which were the principal weapons against destructive erosion of tilled ground, were costly to construct and maintain and slowed field work. As farmers bought larger machinery to increase efficiency, the many terraces became a problem (Behn 1982). Few grain growers chose the terracing option. Harry Young's strategy to minimize erosion was crop rotation: cropping only three years and then rotating back into timothy or fescue sod.

But, conventional tillage had additional problems. Whether corn fields were plowed in the fall or spring, the pressure to finish field tillage and spring planting as quickly as possible was intense. The more ground one plowed, the more one could plant, but plowing was a slow process. Any unusual weather pattern, which delayed field operations, such as an early winter, a late spring, a wet spring, especially a cool and wet spring, only intensified the problem of timely planting of corn (Phillips and Young 1973; Behn 1982). The principal strategy employed by farmers to speed field operations and cut labor costs was to invest in larger tractors and machines, and Harry Young purchased a larger tractor. Although this enabled him and other farmers to reduce costs per acre and increase the size of fields, there was increasing evidence that the preparation of a fine seedbed with large tractors packed the soil (i.e.,

destroyed soil structure) and reduced water infiltration.<sup>12</sup> Thus, the objectives of cost saving and better soil structure favored minimizing tillage operations.

These problems increased the attractiveness of various “minimum tillage” approaches, which reduced field work time, improved soil structure, and provided extended protection of vulnerable soils (Phillips and Young 1973; Behn 1982).<sup>13</sup> With plow-plant, wheel-track, ridge-tillage, or strip-till planting, a farmer could leave crop residue on the field until he was ready to plow, or till, and plant. The presumed benefits of plowing in fertilizer, burying residues, and aerating the soil were still present. These planting techniques reduced the number of trips over the field, thereby reducing labor time, costs, erosion, and soil compaction. By 1960, several machinery manufacturers had “mulch planters for sale or under development.”<sup>14</sup> Some farmers in Kentucky and most midwestern states had become convinced that these minimum tillage techniques were advantageous.<sup>15</sup>

But, other farmers using or observing these techniques found that there were serious problems that made them hesitate to change from conventional tillage (Phillips and Young 1973; Buchele 1967). The critical difficulties involved weed control and the slowness of planting. With the plow-plant system, plowing—a time-consuming operation—immediately preceded planting—the acreage that could be planted in a timely manner was much smaller than could be planted if the plowing and seedbed preparation had been done earlier.<sup>16</sup> Moreover, the rough, untilled ground between the rows, especially if the field had been in sod, made subsequent cultivation or spraying operations difficult and reduced the effectiveness of these operations.

Due to the cost of new planters, the planting constraint, and the uncertainty regarding outcomes, most farmers were inhibited in trying such methods. Shirley Phillips was also aware of the problems associated with the new tillage methods. Any presentation of the advantages of various minimum tillage methods to farmers also necessarily included the qualifications. Even though farmers were increasingly adapting these techniques, it was difficult to make persuasive presentations about them.<sup>17</sup>

Harry Young recognized the difficulties with wheel-track and other minimum tillage methods too, and he did not join those who were trying to adapt these methods to their systems of farming. The crux of the issue was plowing. It was necessary to prepare ground for planting, even with the new mulch planters, and it provided, according to expert belief, benefits in burying crop residues as well as fertilizer, aerating soils, aiding infiltration, and the like. But, plowing also created problems. If corn

could be grown in untilled ground, as the early advocates of minimum tillage claimed (Faulkner 1944, 1952), and if a satisfactory method of planting corn in untilled ground could be devised, the plowing problem could be avoided. Then it would be a matter of satisfactorily controlling weeds.

The potential solution to the weed control problem appeared with information on the effectiveness of the new preemergent herbicide—Atrazine—in controlling grassy and some broadleaf weeds. As the 1961 season approached, Harry Young decided to repeat the test of total weed control with chemicals, this time using Atrazine. Following label recommendations, Harry sprayed Atrazine on seventy-seven acres immediately after planting corn. Although this did not kill all weeds, there were fewer weeds than in the cultivated field. As one of the first tests in using Atrazine for this purpose, the trial attracted the interest of Reeves Davie, Shirley Phillips, and local farmers, and was publicized in *The Progressive Farmer* (Young 1961).

Harry Young was not alone in 1961 in recognizing plowing as the critical factor in devising successful minimum tillage methods. Although no-tillage planting had been tried successfully with other crops, there was little information on whether or how it might be done with row crops, including corn (van Es and Notier 1988). Between 1959 and 1961, researchers at several different Agricultural Experiment Stations had started experiments to answer some of the basic questions on no-tillage corn. How did tillage affect plant growth? What planting rate and depth should be used? What combination of herbicides would satisfactorily kill vegetation and control regrowth? How could existing planters be modified to plant without tillage? Although agricultural scientists obtained information about these ongoing studies through scientist networks, information was not generally available until the experiments were completed and the results published. In 1961, the only research published was of an initial study of the tillage effects on raising corn by scientists at the Virginia Agricultural Experiment Station. Notably, agricultural scientists at the Kentucky Agricultural Experiment Station were not yet interested in studying no-tillage cropping.<sup>18</sup>

### *Linking the Local and the Global Networks*

For farmers in western Kentucky, however, some of the most interesting crop and livestock research was being conducted by the University of Illinois Experiment Station at Dixon Springs in southern Illinois. Soil, topographic, and climatic conditions were similar to western Kentucky. Crop varieties that did well there could usually be counted on to do well

in Christian County. Some of the farmers, as well as Reeves Davie, had been to field days at Dixon Springs.

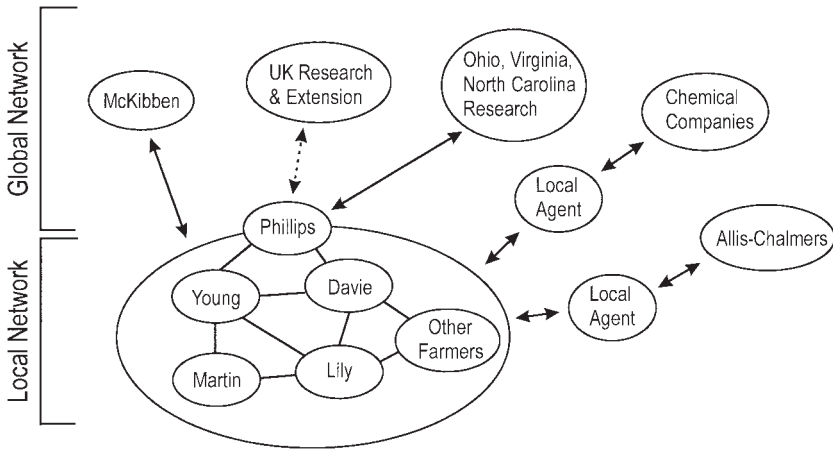
In late June 1961, Alex Breame asked Reeves Davie if he would organize a field trip to Dixon Springs (Davie 1996, 1999). Although the annual field day already had been held, Davie organized a trip in early August to see the experimental cropping trials. Harry Young, Jr., was one of the fifteen farmers who went on the trip.

Not until they began viewing the corn production trials did the group discover that one of George E. McKibben's plots was radically different from the rest. It was a partial trial of corn planted in killed, untilled, sod. It was not a full-fledged experiment because the plot had not been replicated because the machine developed to plant in sod had broken down. But, the corn in that one plot looked as if it would yield very well; the ears were already well formed (Davie 1996, 1999). Harry Young was captivated by the notion of planting in sod without tillage, and in the fall he wrote to Superintendent Robert J. Webb at Dixon Springs for the yield results. When he found that the yield of the no-till plot exceeded that of the conventional trials, he decided to do a trial of his own on 0.7 acre in the 1962 season.

Harry Young applied Atrazine at the rate of 2 1/2 pounds per acre to kill the lespedeza and provide preemergent weed control. He modified an old two-row wheel-driven planter, which he had discarded, by mounting drums on it, which he filled with water, so that the planting shear could be forced into the untilled lespedeza sod (it would not penetrate grass sod). He hoped to gain some experience and compare yields of the no-till plots to yields in their conventionally prepared fields. As the season progressed and the no-till corn looked good, Harry Young worked with Reeves Davie to set up a field day for other farmers and interested officials to see the demonstration of no-plow corn. Although complete weed control was not attained, the corn yield was comparable to that in the conventionally tilled field. The success of this initial trial persuaded E. C. Martin and E. G. Burks, two nearby farmers, to join in trials of no-till corn in 1963 (Fig. 5.1).

E. C. Martin came up with a novel solution to the problem of no-till planting (Davie 1999). On the hydraulic-operated, front-mounted row cultivator of his Farmall tractor, Martin mounted a disc coultter to cut a slot in the ground into which the shear of the planter trailing behind the tractor planted and covered seed. The idea anticipated the development of the Allis-Chalmers planter in 1966, and the system worked well enough that Harry Young adapted his tractor and cultivator in 1964 to use the same technique.

Figure 5.1 Tillage innovative networks in Christian County.



Satisfactory weed control, however, was an important problem not solved satisfactorily in 1962. Although heavier applications of Atrazine would give better weed control, the residual herbicide reduced plant populations of subsequent small grain crops. In 1963, Harry Young decided to set up an experimental trial with variable Atrazine applications to determine the minimum amount needed to provide satisfactory full-season control of grasses<sup>19</sup> in no-till corn production. He also found through continued contact with Webb and McKibben at Dixon Springs that they were using a herbicide—Paraquat—that had been used successfully to kill pasture weeds and weeds in orchards in western states and to knock down growing plants on sod prior to no-tilling corn. For the 1963 season, Harry Young, Jr., placed an order for Paraquat with the local chemical supply firm. By using Paraquat to knock down the covering crop, less Atrazine could be used, thereby solving the problem of the residual herbicide in the field.

Reeves Davie handled much of the local publicity about the no-till trial, and that fall he held an extension meeting for other farmers and extension workers to view and discuss the successful outcome. With variations, the demonstration trials of no-tillage corn and the extension meetings were repeated each fall of the next 2 years (Davie 1996).

Although uncertain that the corn would produce well because all agronomists knew that the best corn production could be produced only on ground that was plowed and with the fertilizer tilled in, Shirley Phillips had been an interested observer of the initial trial in 1962. He

was familiar with research in Virginia showing that corn could be grown successfully with no-tillage (Phillips and Young 1973), and he had read *Plowman's Folly*, (Faulkner 1943) and other publications (Phillips 1992). He counseled with Harry Young on the 1963 no-till herbicide trials and was a key advisor thereafter. By 1964, Shirley had become convinced that no-till corn could be grown successfully, and he began to promote no-tillage with other extension colleagues. By 1965, most of the skeptics in the Kentucky Extension Service and Experiment Station had been persuaded by the success of the Christian County farm trials that no-tillage corn production in southwestern Kentucky was feasible.<sup>20</sup> It was important to begin promoting this new system of no-tillage corn production as a practicable alternative to either conventional tillage or wheel-track planting.

The lack of a satisfactory no-till planter was a major constraint to no-till corn production. But, by the 1966 season, about twenty farmers in Christian County had managed to modify,<sup>21</sup> or were able to borrow, modified planters and had tried or were ready to try growing no-plow corn.

This provided a substantial opportunity to evaluate no-plow corn production. Reeves Davie (1996) appointed a planning committee to organize and publicize a field day on four of the farms in the fall. He was aided in spreading information about no-tillage and publicizing the field day event by the area organization of the Cooperative Extension Service.<sup>22</sup> Christian County is located in the ten-county Pennyrile Extension Area. Periodic meetings of the area agents as well as his meetings with farmers in other area counties as farm management specialist afforded opportunities to talk about the benefits of no-tillage and to present information about the forthcoming field day. Shirley Phillips' and Harry Young's contacts with other extension agents also were useful avenues of publicity.

When the field day was held, 325 people from nineteen counties registered (Davie 1996). Special invitations went to George W. McKibben and others from the Dixon Springs Experiment Station as well as to Kentucky Experiment Station and Extension Service personnel. The notables toured the four farms and discussed the results of the trials with the farmers.

In talking with George McKibben that day, Reeves Davie suggested that they ought to be trying to no-till soybeans in sod because he had seen soybeans growing in wheat in Graves County (Davie 1996, 1999). The group, including Harry Young, Jr., discussed the possibility of growing no-till soybeans after harvesting wheat or barley. Harry Young had previously grown no-till sorghum in wheat stubble, and he decided to try no-tilling soybeans after wheat in the 1967 season.



*Extending the Global Network*

The lack of a suitable no-till planter, which up to that time was the major constraint to no-tilling, was removed by the availability of new Allis Chalmers no-till planters through a local dealer.<sup>23</sup> Harry Young bought one of the new two-row planters. But, a number of important questions were still unanswered: Compared to full-season soybeans, how much a yield penalty would there be from the late planting of double-crop soybeans? Would the profits from wheat and double-crop soybeans exceed that of full-season soybeans? What herbicide treatment would provide the most satisfactory chemical weed control? Was it necessary to chop the wheat straw before no-tilling? Harry Young worked with Shirley Phillips to set up trials to help answer these questions (Davie 1996).<sup>24</sup>

McKibben also took up the idea and in 1967 set up several experiments at Dixon Springs on the performance of soybean varieties at different row spacings in killed sod. The results of these experiments answered many of the initial questions about row spacing and double-crop soybeans.

With Reeves Davie heading the planning committee, a field day again was held in the fall. It was publicized through the extension network and local papers. Speakers were invited from Virginia Agricultural Experiment Station as well as Dixon Springs and the Kentucky Agricultural Experiment Station. The night before the field day, a dinner was held in a local hotel for the twenty-five or more professional people attending the conference. At a roundtable question-and-answer session after dinner, Shirley Phillips discussed no-till research and demonstration work around the state with the professional workers (Davie 1996). The next day, 725 people from eighteen states registered for the morning presentations, filling the auditorium at Hopkinsville Community College, and in the afternoon the group toured the no-till corn and double-crop soybean trials on Harry Young's and one other farm.

In 1968, trials of herbicide applications and soybean varieties with double-crop soybeans were set up on Harry Young's farm (and other farms) to provide answers to additional questions. The field day that fall on no-till corn and soybeans was attended by more than 800 people (Davie 1996).

Harry Young continued to work with Shirley Phillips and the weed specialists for several years in setting up soybean and herbicide trials<sup>25</sup> to minimize or eliminate problems of weed control and production of double-crop soybeans. For the next two decades, the Young farm (as well as other farms in the area) was a prime site for extension-sponsored groups to view no-till crop production.<sup>26</sup> But, 1968 was the last of the big field days in Christian County—but not in other areas—due to dwindling interest and the opposition of some local farm leaders who



thought sufficient attention had been given locally to the new tillage methods (Davie 1996).

*Mobilizing the "Global" Network: Research and Extension*

Using "notions" tried by McKibben, "no-plow," or no-tillage, corn and soybean production was socially constructed by a Christian County, Kentucky, network with limited outside resource support. Chemical herbicides developed for a wider market were adapted to specific tasks of killing grass sod and controlling grassy and broadleaf weeds in corn and soybeans. Planters designed for finely tilled ground were modified by farmers to plant in some kinds of killed sod. But, no-tillage could not become widely practiced, even locally in Christian County, until a satisfactory no-till planter was developed and became available. For the new tillage system to develop fully, and to be successfully reinvented and adopted in other areas, substantially greater agricultural research and technical resources would have to be mobilized.

The received wisdom among agronomists at the College of Agriculture, University of Kentucky, in the early 1960s (as well as agricultural scientists and extension workers generally) was that corn ground had to be plowed and fertilizer incorporated to obtain high yields. Plow-plant was the only method of reduced tillage for which there was sufficient experience to justify official approval (Phillips and Loeffel 1963). "No-plow corn cannot be successful," was a common refrain. The successful performance of Harry Young's no-plow corn plots in 1962 did not prove anything. Probably, it was an aberration. Wait until next year! Shirley Phillips was often chided by fellow workers for his interest in the Christian County no-plow trials (Davie 1996). But, as corn yields of Young's annual trials continued to equal or exceed conventionally planted corn, and as more research at other Experiment Stations was published (van Es and Notier 1988; Phillips and Young 1973), opinion among Kentucky extension workers and scientists began to shift.

Through Harry Young, Jr., and Reeves Davie, the success of the on-farm trials in Christian County got back to McKibben at Dixon Springs, stimulating further work there with corn and soybeans (Davie 1996). Meanwhile, there were ongoing research programs on no-tillage crop production at Virginia Tech, Ohio State, and Purdue (van Es and Notier 1988). Kentucky agricultural scientists, however, were slow to take up the challenge. The first studies of no-tillage at Kentucky were in pasture renovation. But, the problems encountered with no-tillage began to draw scientists' interest. One of the problems that Young and other farmers soon found in using Atrazine at the rates necessary to control grassy weeds was that chemical residues in the soil were toxic for subsequent

small grain crops. Another problem was whether and how no-tillage corn could be grown in other places in Kentucky (e.g., central Kentucky) and what herbicide applications were necessary to kill native grass sod and control weeds.

By 1965, Shirley Phillips was able to persuade J. F. Freeman and other weed scientists at the Kentucky Agricultural Experiment Station to begin addressing these problems. It was found, for example, that phytotoxic residues in soil could be reduced and satisfactory weed control obtained by combining two different preemergent herbicides at much lower rates (e.g., Atrazine and Lorox) and that Paraquat plus Atrazine at a low rate was better than Atrazine alone in killing bluegrass sod for no-tilling.<sup>27</sup> From this point, research on no-tillage crop production began to devise better herbicide applications and to determine that no-tillage crop production need not necessarily be limited to western Kentucky. But, research understanding was quite limited.

As Shirley Phillips (1992) later recalled: "We knew what was happening [e.g., that no-till corn was productive,] but we couldn't quite figure out why it was happening." Research was needed on the underlying processes. Why did no-till corn yield better than conventional in dry years? Why was it unnecessary, as had been supposed, to plow in lime, phosphates, and other minerals? How did they move into the soil? Does plant utilization of fertilizer vary by planting date? In 1968, agricultural scientists at the Kentucky Agricultural Experiment Station began to address these and other underlying questions and to build understanding of no-tillage crop production.<sup>28</sup> By 1972, sufficient research knowledge had been accumulated by agricultural scientists at the Kentucky, Virginia, Ohio, and other research stations to hold the first of a series of research symposia and conferences on no-tillage cropping.<sup>29</sup>

Extension administrators, most specialists, and agents were as skeptical as the agricultural scientists of the benefits of "no-plow" corn production. However, the success of the farm trials in Christian County, as well as the demonstrated interest of other farmers in the new tillage system, encouraged the Kentucky Cooperative Extension Service to break its official silence and endorse the method. Under the headline "No-Tillage Corn Production Growing," the 1966-67 Biennial Report of *Cooperative Extension* reported:

Planting corn in sod, after killing the sod with herbicides and using special planting equipment, is undoubtedly one of the most promising new grain production practices. . . . [It] offers superior erosion control, frequently increased yields, and possibly reduced costs . . . better timing of operations, a low capital investment, a low horse-power requirement, and it does not leave the field in a rough condition undesirable for harvesting.

Although research elsewhere had indicated that erosion on no-tilled corn fields was much reduced (van Es and Notier 1988), the economic benefits attributed to no-tillage were based entirely on Harry Young's (1968; Davie 1996) records insofar as there were actual data to support them. The last statement regarding the lack of roughness of no-tilled fields was an obvious comparison with the plow-plant method.

When Allis-Chalmers began marketing their no-till planter in 1967, Shirley Phillips persuaded the Extension Administration to purchase four for use in establishing no-tillage throughout the state. A team consisting of a crops specialist (Shirley Phillips), a weed specialist (James Herron), and an agricultural engineer (Robert Stewart) had responsibility for conducting no-till trials in counties with the assistance of the county extension agents and cooperating farmers. Over a three-year period, plots comparing no-till and conventional corn and soybean production were planted in eighty-five of the 120 Kentucky counties (Phillips 1992). Each year, field days were held to view and discuss the results. Although the team approach was discontinued, the strategy of comparison trials in counties when farmers and the local agricultural extension agent indicated an interest in no-tillage was maintained (Bitzer 1995).

### *Mobilizing Machinery Companies*

Although the increasing numbers of farmers interested in minimum tillage had created a small market for mulch planters, the major commercial opportunity in the mid-1960s was for ever-larger planters for use on conventionally tilled fields. Although there was increasing interest in reduced tillage, interest of farmers in planters for "zero-tillage" seemed remote. Only one company—Allis-Chalmers—was working to develop such a machine. Nevertheless, by 1965 Allis-Chalmers had developed an "experimental" planter that was designed to plant directly into killed sod or crop residue.

In summer of 1966, Harry Young learned that Allis-Chalmers was "experimenting with a no-till planter" (Davie 1996). He asked Reeves Davie to see if Allis-Chalmers could be persuaded to send one of the experimental planters to Christian County. The Hopkinsville dealer had not heard anything about it, but suggested that Davie inquire about the possibility of such a machine at the District Sales Office in Memphis, Tennessee. When Davie went there, the sales manager informed him that the planter was no longer experimental but in production and that machines could be purchased.

When Davie returned with a description of the new planter, Young and five or six other farmers immediately said they would like to purchase one, whereupon the local Allis-Chalmers dealer who received the

orders and was aware of the interest in no-tillage requested a dozen of the new planters. This prompted the Memphis District Manager to come to Christian County to find out what was going on. The Memphis District Office had received only ten new planters, one for each of the southern states in the district, but the Christian County dealer had requested all of them. Davie was more than happy to show him how farmers had become interested in no-tillage, and Allis-Chalmers willingly agreed to become one of the financial sponsors of the 1967 no-till field day. By 1969, the Hopkinsville dealer had sold sixty-eight no-till planters, and another dealer who started selling that year sold fifteen in 1969 alone (Choi 1981).<sup>30</sup>

### *Mobilizing Chemical Companies*

Expansion of sales of weedicides—Atrazine, Lorox, Paraquat—in Christian and nearby counties soon attracted the interest of chemical companies. For example, the limited sales of Paraquat, which had been developed as a contact herbicide in 1959 and was distributed in the United States by ICI Americas, were primarily used in pasture renovation and in western orchards. In the early 1960s, Chevron Corporation purchased the rights to market Paraquat. In 1966 and 1967, the sales of Paraquat in Kentucky, especially western Kentucky, jumped dramatically, and one day a visitor—a Chevron of California sales representative—walked into Shirley Phillips office searching for an explanation of the sudden increase in sales of Paraquat (Phillips 1992). Shirley Phillips and James Herron (weed specialist) gave the Chevron representative a tour of the no-till plots on the Agricultural Experiment Station farm. It was not difficult for the salesman to begin estimating the potential increase in sales of Paraquat and other chemicals. Similarly, Ciba-Geigy (Atrazine), DuPont (Lorox), and Monsanto (Ramrod) quickly became interested in no-tillage and sponsors of experimental trials and field days. More importantly, the chemical companies expanded their research and development of new and more effective herbicides.

## Constructing Innovative Networks on the Darling Downs, Queensland

### *Local Actor Networks*

As the cultivation of small grains expanded on the Darling Downs during the 1930s, the Agriculture Branch of the Department of Agriculture and Stock began to address the increasingly serious problem of soil erosion. Starting in 1935, responsible officers began surveying and con-

structing contour banks for cooperating landholders in the Pittsworth, Pilton, Greenmount, and Kingaroy areas (Skinner et al. 1977; SCB 1976). Following World War II, demonstration farms were established by officers of the Bureau of Investigation for the purpose of demonstrating conservation techniques, such as contour banks, strip cropping, and stubble mulching, to farmers. The demonstration farms also facilitated the development and testing of conservation methods and the training of field officers. The field days held on these farms attracted large numbers of farmers.

Mr. Hector H. Tod of "Popular Farm" near Jondaryn is credited with being the first farmer on the Downs to begin strip cropping (Skinner et al. 1977). He was impelled to try this cropping strategy after witnessing the general destruction of cultivated areas caused by the strong storms in January 1956. The flood-borne debris from farms farther up the watershed ended up on his farm (Kamel 1998). Other farmers quickly followed his example, and the area of the Downs "protected by conservation measures"—strip crops, contour banks and waterways—climbed from 1,032 hectares in 1955 to 2,632 hectares in 1957.

In 1962, soil conservation officers in the newly established Soil Conservation Branch led a successful effort to establish a number of Soil Conservation Catchment Groups. Composed of landowners within defined watersheds, the groups met to plan coordinated water management schemes and to exchange ideas and discuss results (Skinner et al. 1977). The groups continued to meet for many years. The Catchment Groups were forerunners of the Advisory Group Committees formed over a decade later under auspices of the Areas of Erosion Hazard (AEH) authority.

By keeping up with overseas developments in soil conservation, field officers acquired a general familiarity with the principles of stubble mulching and the advantages of tined implements over discs and plows in retaining stubble. Through promotion of tined implements, more and more farmers began using these implements in weed control and ground preparation during the 1960s and found that the burning of stubble was less necessary (SCB 1976; Ward 1988). But, inadequacies of the available tillage and planting equipment prevented field officers from obtaining systematic information on the applicability of stubble mulching on the Downs, and prevented farmers from retaining stubble for more than a brief period during the fallow season. After two of the normal four or five cultivations of fallow ground, the stubble mulch would be virtually destroyed, leaving the ground bare and unprotected from summer storms.

*Mobilizing Global Actor Networks*

The collaboration of Soil Conservation Branch officers and farm leaders, however, produced initiatives that enabled grain growers on the Darling Downs to begin changing their tillage practices.<sup>31</sup> The field officers knew that a broader range of better stubble handling equipment was available to grain farmers in the United States and Canada. Both the need for better stubble-handling equipment and its availability overseas was shared among members of such groups as the Council of Agriculture (Qld.), of which Mr. J. Jones, Director of the Soil Conservation Branch was Secretary, and H. H. Tod of "Popular Farm"—early adopter of strip cropping—was a member and enthusiastic supporter of programs to improve soil conservation methods.

Through their initiative, funds were obtained from the Queensland Department of Primary Industries (DPI) to finance a trip by H. H. Tod and G. L. Swartz (SCB officer) to the United States and Canada in August–September 1969 to thoroughly investigate the stubble mulching techniques and machinery in use there (SCB 1976). Upon returning to Queensland, they recommended that particular types of chisel plows and trash drills be imported so that the equipment could be tested and evaluated under Australian conditions and that SCB officers could develop stubble-mulch cropping systems.

Mr. J. Jones and members of the Council of Agriculture (Qld.) quickly endorsed this recommendation and immediately engaged representatives of American- and Australian-based machinery manufacturers in discussions aimed at acquiring the desired types of equipment. Because the Australian machinery manufacturers had equipment adapted to southern conditions already on the market, they were reluctant to cooperate in an endeavor with such small marketing prospects. However, John Deere Australia, Ltd. agreed to the request. Four items of equipment were imported in November 1969 and immediately released to the DPI for testing and evaluation under auspices of the Council of Agriculture (Qld.).<sup>32</sup> With Deere leading the way, both Case Australia Ltd. and J.T. Ellis and Sons (Kingaroy) also expressed interest in participating in the machinery evaluation programme (SCB 1976).

*Recreating Local Networks*

Anticipating the imminent arrival of the requested equipment, Mr. Jones (director of SCB) convened a meeting on 6 November 1969 with G. L. Swartz and T. R. Kamel (SCB officers) to develop procedures for testing and evaluation of the stubble mulching and reduced-tillage equipment. They decided to establish a semiformal Machinery Testing Committee (MTC) composed of SCB staff, representatives of firms pro-

viding equipment (if representation was desired), and “farmers nominated by the Council of Agriculture (Qld.)” (SCB 1976, 5-6). Localities for testing particular implements were selected, and farmers were invited to participate in the testing and evaluation.<sup>33</sup>

“The John Deere equipment along with a Lilliston Mulch Tiller was first operated in the field on Mr. N. Redding’s property at Mt. Tyson, Eastern Darling Downs, on the 3rd of December 1969. A small group of farmers were selected in that locality to work and evaluate the equipment in the field under the supervision of personnel from the Department of Primary Industries who were members of the MTC. Questionnaires were given to the farmers so that records could be kept of the machinery’s performance” (SCB 1976, p. 5.6).<sup>34</sup> The enthusiasm of this group (Machinery Evaluation Committee, MEC) enabled the evaluation program to flourish despite some early problems. (This farmer-centered MEC had a distinctly different purpose than the semiformal, administrative MTC.)

The initial tests indicated that, although superior to existing equipment manufactured in Australia, the chisel and blade plows were not fully satisfactory. The equipment had difficulty handling some of the heavy soils and stumps in newly cleared ground. Although the rod weeder attracted considerable interest, no one wanted to buy it (Ward 1988). But, interest in the machinery testing program spread because of the enthusiasm of the members of the MEC for the testing of new and different types of equipment. Mr. Tod adopted the press wheel drill and most of the other technology. Many others saw the benefit of press wheels in improving establishment of summer crops (Ward 1988). Several more farmers began modifying equipment to improve stubble handling capability.

### *Local-Global Network Interaction*

Following the success of the testing program in 1969–70 and the amalgamation of John Deere Australia with Chamberlain in 1971, the Council of Agriculture (Qld.) and the Queensland DPI made representation to the Federal Department of Agriculture (Australia) for financial assistance to purchase additional stubble mulching equipment from John Deere. In mid-1972, the Commonwealth Government approved this proposal, and funds allocated to Queensland enabled the DPI to purchase additional equipment.

The 1971–72 cropping year was a watershed in the machinery testing program. With the additional equipment, the program could be expanded and the equipment demonstrated, tested and evaluated under the conditions prevailing in different localities. Testing and evaluation



programs were started in the Southwest under the direction of Lindzey Ward—the SCB district officer located in Dalby—and in the South Burnett with Mr. T. Kamel primarily in charge (SCB 1976).

Tarek Kamel and Lindzey Ward became key figures in the testing, evaluation, and development of better residue-handling machinery throughout Queensland and northern New South Wales. Both were relatively new SCB officers: Tarek Kamel had joined in 1967, and Lindzey Ward had joined in 1966 after graduating with a Primary in Agriculture from Gatton Agricultural College (Ward 1988). As a trainee in soil conservation, Lindzey Ward was moved from one district to another before being assigned to the Dalby District in 1969 as District Officer. In the course of this training, Lindzey had gained an interest in farm planning from Colin Gillis (District Officer at Emerald), and in coming to Dalby, he was strongly influenced by Rex Kelsey's (Regional Officer in Charge) views on the importance of maintaining organic matter in soils and the harm done by burning stubble and by erosion. These interests guided his approach to machinery evaluation in the early 1970s.

Lindzey Ward conducted the initial demonstration trials in 1971 on several cooperating farmers' fields in the hilly areas northeast of Dalby. The fields were so dry and rough that ordinary drills could not be used. But, with the John Deere press-wheel drill, he planted and successfully established a crop of winter oats for forage.

The next summer (1971–72), which was unusually dry, Ward offered to use the John Deere drill to plant fifty acres of crop on anyone's property who wanted it. More than forty farmers accepted the offer. However, because their properties were relatively small, the idea of purchasing the new equipment did not appeal to most of the farmers. Only two farmers were initially willing to adopt the press-wheel technology and build a press-wheel planter similar in design to the John Deere (Ward 1988).

Faced with this lack of interest, Lindzey Ward shifted the testing program in 1972 to the plains southwest of Dalby. One of his first activities was a demonstration field day. The field day was well publicized, and 350 farmers came to the demonstration. Neville Ronnfeldt, as well as Hector Tod and several other farmers in the near southwestern plains, were quite interested in the new technology, and Lindzey Ward began working with them on ways to improve the performance of the new equipment and how existing equipment might be modified to work better.

The widening interest of farmers convinced Graeme Swartz (and other SCB administrators) that Lindzey could be more effective if he could move his equipment around more easily. With SCB support, Ward acquired a truck with a crane to load and unload the equipment. When the machinery testing program was expanded in 1974, G. Lehman



acquired similar equipment to facilitate work in the Darling Downs Upland (Ward 1988; SCB 1976).

Although tests of the new stubble-handling equipment on the eastern and western Downs in 1970 and 1971 demonstrated their general applicability, the equipment itself was not generally available. The blade plow in particular, which was the most important implement from a stubble-retention standpoint, was not available. For commercial reasons, John Deere was not interested in importing the plows for sale, and Napiers Bros. felt that it would not be profitable to design and develop a frame strong enough to handle the large 6-foot blade. Thus, early on SCB officers had little to suggest for farmers who wanted to acquire blade plows. Nature soon intervened to change the situation substantially.

During the summer of 1972–73, severe thunderstorms pounded the length and breadth of the Downs, resulting in one of the most extensive erosion events ever experienced. This event prompted the Queensland government to declare eleven shires on the Downs Areas of Erosion Hazard (under provisions of the 1965 Soil Conservation Act). Under provisions of the declaration, farmers were required to carry out conservation measures—construct contour banks and waterways and use best management practices. The government provided incentives in the form of subsidies. In September 1973, a matching subsidy up to \$500 was made available for the modification or purchase of equipment for minimum tillage or construction of conservation works.<sup>35</sup> This immediately increased the demand for more machinery for demonstration and testing purposes, and funds were provided to the SCB to purchase four minimum tillage machines in January 1974 (SCB 1976).

To obtain farmer guidance in selecting the types of machines to purchase, Tarek Kamel, Secretary of the MTC, convened meetings of SCB staff and farmers. The result was a decision to form several MECs on the basis of different landforms and principal farming systems—South Burnett, Eastern Darling Downs, and the Plains (SCB 1976).<sup>36</sup>

### *Recreating the Local Network and Expanding the Purpose*

Up to this point, the program initiative had been sustained by the officers and administrators in the Soil Conservation Branch. The Agricultural Branch, with responsibility for cropping systems and farm management, had not been engaged in the program. But, it was recognized that stubble management had implications for crop management, and the objectives of the machinery evaluation program were expanded to include the adaptation of cropping practices. With this broadened focus, cooperation of the Agricultural Branch was sought, and several agricultural officers subsequently participated in the program and the

MECs.<sup>37</sup> From this point, the interest of agronomists in stubble mulching gradually expanded.

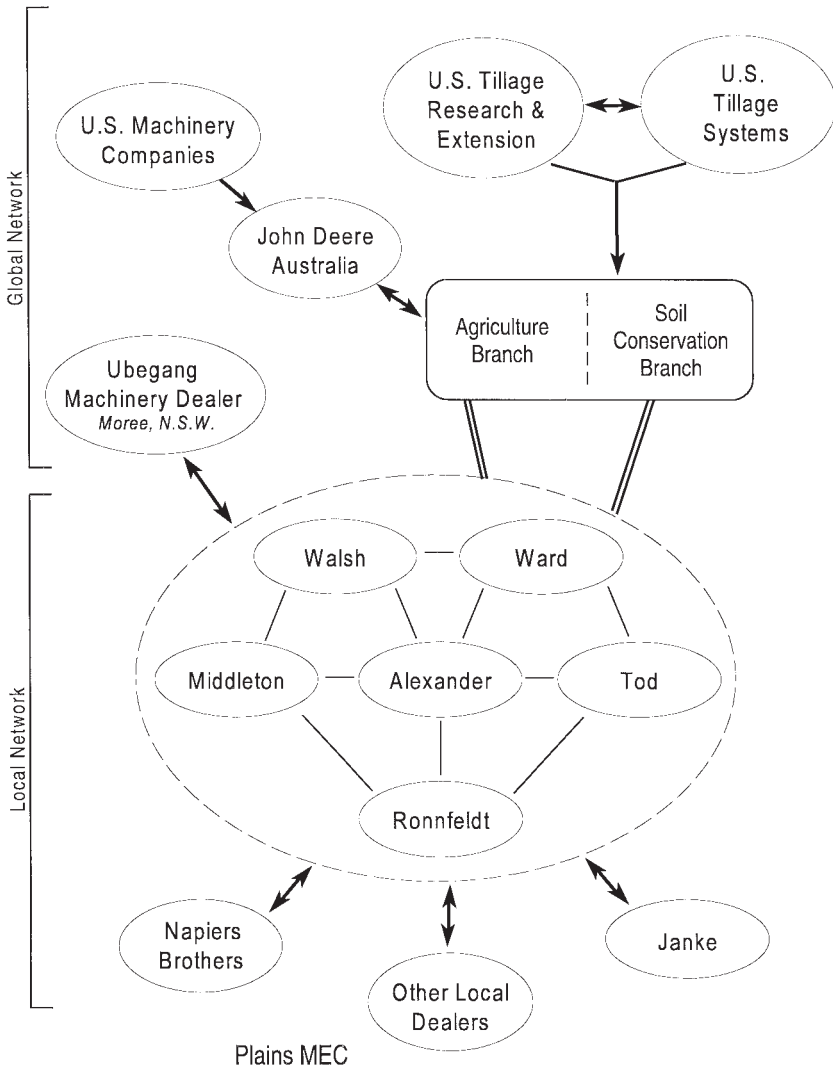
Lindzey Ward drew together several of the farmers with whom he had been working for 2 years or more to form the Plains MEC—Darwin Alexander (Chr.), Max Middleton, Neville Ronnfeldt, Hector Tod, and Stan Walsh (agronomist) (Ward 1988; Ronnfeldt 1988a). This group was particularly active in soliciting involvement of local machinery companies. Representatives of local machinery manufacturers—Janke, Gyal, and Napiers—came to the MEC group meetings to find out what farmers thought about the performance of the equipment and to suggest modifications that might work better. Janke was particularly interested in developing components that would improve the effectiveness of particular machines (Ronnfeldt 1988a; Ward 1988). This generally speeded up the development of improved trash-handling equipment (Fig. 5.2).

The early trials had demonstrated, for example, that, although the 6-foot sweeps of the John Deere would go through stubble and control weeds, the alignment of the 6-foot sweeps on the John Deere plow was difficult to maintain. Napiers already had a piece of equipment—a scarifier with the cultivator feet spaced on three tool bars—which allowed crop residues to flow through the machine.<sup>38</sup> Although the 6-foot sweeps of the John Deere plow required a relatively heavy frame, the three-bar (scarifier) frame was strong enough to handle smaller sweeps. Thus, by fixing 3-foot sweeps to shanks that were bolted to the existing frame, a sweep-type plow could be developed rather inexpensively (Fountain 1988). The shanks were spring loaded to break out if a sweep hit a stump or rock. The resulting demonstrator was lighter, was easier to maintain, and would handle a wider range of field conditions than the American-designed sweep plow. These design characteristics appealed to Neville Ronnfeldt (as well as to other farmers) who had become convinced that the blade plow would save stubble. Ronnfeldt located the demonstrator, brought it to his farm, and after a trial, purchased it (Ronnfeldt 1988a; Ward 1988).<sup>39</sup>

The traditional combine (planter) did not have press wheels, but the advantage in seed establishment of the press wheels on the imported John Deere planter was immediately evident, especially for summer crops—sorghum, sunflowers, maize, and the like. Farmers wanted to add press wheels to their existing planters. The type of press wheel—wide or narrow, single or tandem—and weight that would provide the best coverage and soil-seed contact, however, had not been determined.

To help answer these questions, Lindzey Ward acquired four different types of press wheels from the United States for the MEC farmers to evaluate (Ronnfeldt 1988a). In trials under different soil and moisture condi-

Figure 5.2 Innovative machinery evaluation network on southwest Downs.



tions, the Plains MEC found that a 4-inch wide wheel had the widest application. They contacted Janke, who agreed to manufacture 500 wheels of this design for farmers who wanted to add press wheels to their existing equipment. In a short time, Gyal added press wheels to the TX planter, and others soon followed. Now, press wheels are standard on all planters.

More by coincidence than design, perhaps because Lindzey Ward had been working with the individual farmers before the Plains MEC was formed, this MEC operated quite differently than the South Burnett MEC. Although the aims to evaluate machinery were the same, farmers on the Downs took the lead in identifying the problems with the stubble mulching equipment. Farmers used the equipment, which Lindzey brought to them, and the group offered suggestions on modifying it to make it work better. If the equipment worked well, the question was how it could be obtained. If there were problems, the question was what could be done to improve performance. The testing and evaluation program was substantially farmer-led (Ronnfeldt 1988a).<sup>40</sup> The farmers were less interested in the formalities of testing (and record keeping) than in application on their own properties. Although this lack of concern with the official requirements of the testing program upset the coordinating officers, the farmers made great strides, often with the assistance of local companies, in developing workable equipment.

### *Reengaging Global Networks*

Because of the reluctance of local companies to import machinery, new equipment from overseas was scarce. On one of his demonstration trips, however, Lindzey Ward learned that Colin Ubegang in Moree, New South Wales (N.S.W.), who had just acquired the Versatile Farm Machinery dealership, might be interested in importing some equipment. Following up on this information, Lindzey was able to convince Ubegang of the desirability of importing a blade plow for trial purposes. When it arrived, Ubegang flew Lindzey and several of the western Downs MEC group to Moree to see the Morris blade plow (Ward 1988). As a result of the group's interest, Ubegang imported five of the plows. One was purchased by the DPI and taken to Dalby for demonstration purposes. Two members of the Plains MEC immediately purchased plows, and a field demonstration convinced another farmer to buy one of the blade plows (Ward 1988).<sup>41</sup> This initiated the wider use of blade plows on the Downs, although problems in the use of blade plows limited their adoption and use (Ward 1988; SCB 1976).<sup>42</sup>

Because in the early 1970s, mechanical control of weeds in fallow was the normal practice, the planter that most farmers had combined cultivation and planting operations. The "combe" planter worked fine in clean fallow. But, as more and more farmers tried to retain crop residue during the fallow, they needed a planter that would plant through some stubble. To meet this need, Gyrál Mfg. in 1972 introduced the Gyrál TX planter. It was a six-bar planter and a significant improvement over the "combe" planter in the ability to plant at proper depth through stubble.

Other manufacturers quickly introduced competitive designs. Napiers Bros. developed a six-bar "Trash Seeder," which was based on the original "combie." The additional bars allowed spacing of the planting tines so that a moderate amount of surface residue would flow through the planter (Fountain 1988). Farmers, however, typically chisel-plowed once after harvest, even if double cropping, and if the stubble was heavy, they used a slasher to reduce the stubble before chisel plowing. If the crop rotation called for a normal fallow, the field would also be cultivated two or more times, which further reduced the stubble. Thus, the planter was not required to plant in stubble without prior cultivation.

The scarifier (cultivator) with tines and duckfoot ground tools mounted on four or five bars was widely used to control weeds in fallow. With widely spaced tines, it was able to work in moderately heavy stubble. Mr. G. Lehman (SCB), who was responsible for equipment evaluation with the Eastern Darling Downs Uplands MEC, worked with the Plant & Plant machinery company in Toowoomba in 1974–75 to develop a planter combining the technology of an airseeder (a European innovation) and the scarifier with press wheels as the planting tool. Lehman demonstrated his scari-seeder widely, and it was a successful invention (SCB 1976; Ward 1988).

### *New Directions: Reengaging the Global Network*

By 1975, the testing, evaluation, and development of equipment on the Downs to improve retention of stubble in fallow had been accomplished. The performance capabilities and limitations of plows, cultivators, and trash seeders had been demonstrated. With the information available, little more could be done in machinery development to advance stubble mulching. The Plains MEC, therefore, advanced the idea of sending several people to assess the state-of-the-arts in the United States. Through Hector Tod and the Council of Agriculture, representations for funding were made to the DPI and to private industries (Napiers Bros., Shearers, etc.). Funding was obtained to send four people for a 2-month study to the United States and Canada. In May and June 1976, the team of Lindzey Ward, C.P. Morris (agricultural engineer), Max Middleton, and A. Ellwood (farmers) visited experiment stations and toured tillage and cropping systems from Texas through the Midwest and upper Great Plains into Canada and back into Colorado, Oregon, and Washington (Ward 1988; SCB 1976).

The most striking development, which the team observed in the United States, were the systems of zero-tillage and double cropping. From a cropping standpoint, however, the team report stressed the distinctiveness of the northern N.S.W. and Queensland soils and climate.<sup>43</sup>

For the most part, neither the machinery nor the cropping systems developed for other areas of Australia or in the United States could be transferred to the Downs. Consequently, appropriate cropping and tillage systems for the Downs would have to be developed locally. The team recommended establishment of a coordinated Queensland and northern N.S.W. program to develop zero-tillage systems as soon as possible (Ward 1988).

But, research on herbicide-stubble relationships had been initiated in 1976 in the South Burnett, and administrators were reluctant to expand this initiative. The developing of conservation measures under areas of erosion hazard (AEH), including better management of surface residue, were their top priorities. Most of the manpower and funding resources of the SCB were devoted to developing and implementing project plans for conservation works. Developing a program to develop zero-tillage systems would introduce a wide range of new considerations and deflect attention from the effort to persuade farmers to do a better job of stubble mulching with available knowledge and techniques. Instead in 1976, SCB established the Surface Management Project, to expand knowledge of stubble mulching through the study of water and sediment run-off in black earth and grey clayey soils, under varied surface residue conditions.<sup>44</sup> Members of the MECs were folded into surface management groups to evaluate results of this research.

Although the MECs in the South Burnett and on the Downs had amassed considerable data on machinery performance in stubble cropping, the information was scattered and not generally available for use in seminars or educational forums or by field officers. In 1978, the SCB established a Conservation Cropping Development Group to gather and summarize this information, and in 1980 the group's focus was shifted to the development of extension programs promoting conservation cropping on the Downs (Keith 1988).<sup>45</sup> Due to the failure to recognize the magnitude of the system change required and the demands placed on field officers, however, implementation efforts were unsuccessful until these constraints were later recognized.

Although Lindzey Ward had failed to convince SCB administrators to support research trials on zero tillage, there were other parties in Australia with a keen interest in zero tillage. Monsanto Corporation's new herbicide—Roundup—was much superior to existing knockdown herbicides. Although still under patent and quite expensive, Roundup had become the chemical of choice in the United States for no-tillage in sod or rye cover crops. Potentially, it had wide application for reduced or zero-tillage in Australia, but it was untested in Queensland.

The major chemical companies—Ciby-Geigy, ICI, and Monsanto—had good working relationships with field officers and administrators in the Queensland DPI (Guthrie and Frazier 1988; Scott 1988; Childs 1988; Keith 1988). Through periodic meetings and ordinary contacts, field representatives kept informed of each other's activities, field trials, and findings. One person with particular interest in the 1976 Ward-team trip and their report, which recommended work on zero-tillage, was Ross Fellows of Monsanto Australia.

In 1977, Ross Fellows decided to find out whether Lindzey Ward would be interested in working with him to set up zero-tillage trials. Lindzey's immediate response was, "I'd love to, but my Department's against it" (Ward 1988). But, Fellows persisted, saying that Monsanto would supply the product and do the spraying if Lindzey would organize and manage the trial sites. Ross Berendt, Lindzey's superior in SCB, however, advised Lindzey against becoming involved with Monsanto.

But, the opportunity to engage in this new line of work was so compelling that Lindzey decided to cooperate with Ross Fellows in zero-till field trials despite his supervisor's advice to the contrary (Ward 1988). Lindzey selected six sites in the western region, including Hector Tod, Neville Ronnfeldt, and Max Middleton from the old MEC, for the zero-till trials.<sup>46</sup> As the 1978 winter wheat planting season approached, however, a major constraint developed. The summer had been wet, and the ground had dried hard under the heavy wheat stubble. Lindzey knew that his planter would not be able to penetrate such stubble and hard soils, and to avoid failure he would have to ask his supervisor Ross Berendt for assistance.<sup>47</sup>

Admitting that he had gone against his supervisor's (Berendt) advice to avoid involvement with Monsanto, Lindzey appealed for help. Explaining the situation, he asked for funds to help modify an old chisel plow so that it could be used as a planter. Berendt accepted the explanation, and recognizing the knowledge-building potential of the trials, agreed to provide A\$800 of SCB funds to enable Lindzey Ward to construct a suitable planter (Ward 1988). Lindzey took his chisel plow to G. Lehman's machine shop in Toowoomba, and in three weeks they removed unnecessary parts, mounted a wheel-driven seed box, and added press wheels, thereby constructing a chisel zero-till planter.

At each of the six sites, Lindzey set up three test plots—a plot with conventional tillage and planting, a zero-till plot, and, against Ross Fellows advice, a plot that was cultivated early in the fallow and just before planting with herbicide applications substituted for the middle two cultivations (Ward 1988). Lindzey Ward felt that zero-tillage might be too

radical a step for most farmers who were convinced by common practice as well as by their agricultural advisors that the best way to control weeds in fallow and prepare a good seedbed was to cultivate, cultivate, cultivate. But, he felt some farmers might be able to see an advantage to reducing tillage in saving stubble (and field time and moisture) by substituting herbicides for one or two cultivations. Monsanto applied all the chemicals for in-crop and fallow weed control, and DPI planted and harvested the crops.

Subsequent experience proved the wisdom of this experimental strategy. Although zero-tilled double crops performed best, partial herbicide substitution performed best in normal fallow-crop rotation, especially on black clayey soils (Ward 1985, 1988; Freebairn 1984). Moreover, as Lindzey Ward had surmised, the initial steps, which most of the innovating farmers made, were to substitute chemicals for some, but not all, of the fallow cultivations.<sup>48</sup>

After viewing the trials on his property for eighteen months, Neville Ronnfeldt (and several other farmers who had watched the previous trials) decided in 1981 to cooperate with Monsanto in trying to control weeds in his wheat fallow with herbicides. In September 1982, DPI and Monsanto held a field day on Ronnfeldt's farm, which was attended by a large number of farmers (Scott 1988). The success of this trial encouraged Ronnfeldt to begin substituting herbicides for some fallow cultivations on a regular basis (Ronnfeldt 1988a, 1988b).<sup>49</sup> The benefits of substituting herbicides for some of the fallow cultivations were also recognized by Middleton on the western Downs and Howell near Goondiwindi (Ward 1988). Hector Tod began using zero-tillage when there was sufficient moisture to double crop (i.e., "opportunity cropping"). Through field days and farmer networks involving Tod, Ronnfeldt, Middleton, and Howell, the use of herbicides as substitutes for cultivation in fallow began to spread to other farmers in the early 1980s.<sup>50</sup> Wayne Newton was one of the young farmers who had attended field days on the Tod and Ronnfeldt farms and often discussed conservation tillage with Ronnfeldt and Monsanto representatives. As a result of the 1981 flood damage to his farm, Newton began to substitute herbicides for cultivation in 1982 and subsequently cooperated in Monsanto-sponsored herbicide trials in 1984 and 1985 (Newton 1988a, 1988b).

Meanwhile, Monsanto began sponsoring herbicide trials in the central and eastern Downs, and other chemical companies began to follow suit. In 1981, ICI Australia moved to expand its market in Queensland and northern N.S.W. for Sprayseed (a replacement for Paraquat) and Gleen, which they were marketing for DuPont (Guthrie and Frazier 1988). The market development strategy entailed conducting field trials



with cooperating farmers who were identified by local sales representatives. Small-plot developmental research as well as large-plot demonstration trials were conducted. From a developmental research standpoint, ICI wanted to determine what combinations of herbicides would produce a weed-free environment at wheat harvest. This would make maintenance of a weed-free summer fallow a much easier task. Proven herbicide strategies would be demonstrated on large field plots. Between 1981 and 1985, such trials were conducted over a wide area, and the market expanded substantially.

This expansion, along with changes in cropping systems, coincided with expanded networking in the eastern Downs. Network expansion occurred, not merely because of increased activity by chemical companies, but also because of expanded advisory activities by SCB and Agriculture Branch field officers and greater initiatives on the part of innovative farmers to change tillage systems. A 1982 study of farmers' attitudes and stubble mulching practices on the Downs (Chamala et al. 1983) not only indicated widespread lack of knowledge and skill among farmers in using machinery and herbicides for residue management but also among field officers. The SCB immediately initiated training programs designed to increase the competence of field officers in working with blade and chisel plows, rod weeders, and trash planters (Ward 1988; Keith 1984, 1988). The gain in field officers' technical competence also increased their interest in advising farmers on stubble mulching problems.

The coincidence of a cost-price squeeze, the decline in the price of Roundup, which was no longer protected by patent, and several wet seasons in the early 1980s increased grain growers' incentives to make changes in their tillage practices. Between the 1979–80 and 1982–83 financial years, increases of 57 percent, 40 percent, and 32 percent occurred in the indexes of prices paid for fuel, machinery, and labor, respectively (Scott 1988; Ward 1985). Meanwhile, the index of prices paid for chemicals increased only 28 percent, and the prices received for wheat increased only 22 percent. The much more modest rise in chemical costs, relative to other farm inputs, thus made the use of herbicides to control weeds an increasingly favorable economic option. Moreover, the more rapid rise in farm costs compared to income from farm sales compelled farmers to seriously consider changes in farm practices that would slow the rise in farm costs.

Summer storms were particularly severe during 1981 to 1983, and the extended wet periods kept most farmers from getting onto paddocks to control weeds with heavy tractors and scarifiers or cultivators. However, farmers could use lighter equipment, such as boom sprayers mounted

on a truck or a small tractor, or they could use aerial spray to control weeds.

Weather events and/or rising farm costs coinciding with contacts with chemical company representatives, Agriculture or Soil Conservation Branch officers, and other farmers were the influential factors cited by Peterson, Newton, Noller, Heard, and Bell in deciding to try substituting herbicides for cultivation in fallow weed control.<sup>51</sup> Through the late 1970s and early 1980s, when Wayne Newton was making changes in his cropping and tillage system, he was in periodic, if not regular, contact with Hector Tod and Neville Ronnfeldt, two of the veteran innovators of conservation tillage on the southwestern Downs. He credits both with providing helpful advice on various aspects of his new system.

On the eastern Downs, 150 kilometers (90 miles) from the Dalby area, Rod Peterson learned about the innovative tillage systems on the western and central Downs and South Burnett through articles in the *Queensland Grain Grower*, *Queensland Country Life*, and periodic contacts with SCB and Agriculture Branch officers. Through these sources of information, he became convinced of the need to save stubble and of the usefulness of a chisel plow, which he purchased in 1970. Rod Peterson maintained relationships with DPI officers, and he became recognized by them as an innovator in conservation tillage. It was not coincidental then that when DPI officers received funds to conduct tillage-herbicide trials in 1983, Ken Bullen (Ag Branch agronomist) went to see whether Rod Peterson would be interested in cooperating. He was. While Peterson determined the alternative tillage systems for experimental trials—conventional tillage with discs, stubble mulching with chisel and blade plow, and herbicide substitution where possible—Tom Crothers (SCB conservationist) discussed the options and advised how best to obtain reliable comparative data.

The idea for double cropping with available moisture was the result of a conversation between Rod and Tom Crothers at the end of the second year of trials (1985) after an unusually wet winter. When Rod Peterson questioned what next step should be, Crothers (1988) responded that "In my opinion, if there is enough moisture for weeds [to grow], there should be enough moisture for a crop." Rod readily agreed and decided to plant soybeans. Although the stand was satisfactory, a late summer drought severely reduced the yield. But, the experience proved the value of opportunity cropping into moisture, which stubble from the previous crop helped to maintain. The strategy subsequently proved very profitable.

Rod Peterson's mechanical engineering ability made him an exceptional farmer, one particularly likely to succeed in the construction of an

innovative tillage system (Carlson and Dillman 1988). Rod recognized that the equipment—planters and sprayers—that he could purchase were not satisfactory for the tillage system he desired and set about constructing his own implements. As the first step, Rod expanded his information network to include Lindzey Ward and Hector Tod from whom he obtained ideas on openers, planting tines, press wheels, spray regulators, mixers, and the like (Peterson 1988a). With Crothers' encouragement, Rod Peterson entered and won the 1984 Queensland Country Life Soil Conservation Competition with a summer-crop planter constructed out of Janke parallelogram planting units, special tines, coulters, and press wheels.

Innovativeness with machinery and herbicide-trial field days held on his property from 1983 to 1985 made Rod Peterson a key source of information for other farmers, including Neville Heard,<sup>52</sup> and a leader in conservation tillage and opportunity cropping through the Conservation Tillage Center in Dalby.

The coincidence of pressures on farmers to reduce costs of weed control, ICI Australia's interest in finding farmer cooperators for herbicide trials, and Agriculture Branch interest in improved conservation tillage brought Roy Noller, Ian Moore (Noller's son-in-law), Colin Holley, and Colin Bell together as a core network (Bell 1988, 1995; Noller 1988, 1995). This informal MEC network used one of Noller's blocks (fields) as a trial site for several years during the mid-1980s while they worked collectively to develop more satisfactory planters, sprayers, herbicide applications, and crop rotations. Ken Bullen, Peter Pierce, and Jim Hitchner (agronomists) and Mitch Hook (ICI Australia) provided advisory assistance and in turn gained valuable information from the network members' successes and failures. Individual members of the network also obtained advisory assistance from representatives of other chemical companies as well as earlier farmer innovators.<sup>53</sup>

Various members of the Noller-Bell network had close relationships with neighboring farmers who made contributions and shared experiences. In his farming operation, Colin Bell partners with his father and brother, who have been effectively members of the network through Colin Bell (Bell 1995). Bell in particular continues to network with other farmers in his neighborhood, as did Noller until he began working for Pioneer Hybrids in 1994.

When Neville Heard moved to the Downs, he had no local network of established friends (Heard 1988). The only people he knew were the farmers who had farmed his new place before him. Of necessity, he set about constructing an information network. This included DPI officers at the nearby Hermitage Research Station and in the Soil Conservation

and Agriculture Branches in Warwick. He also went to field days and picked up some information during the early 1980s from Rod Peterson.

However, his aggressive networking and innovative conservation tillage system development have contributed to his becoming a local opinion leader, especially in herbicide applications. In 1990, Ken Bullen (DPI agronomist) established a comparative trial of zero-tillage, minimum tillage, and conventional tillage on Heard's place.<sup>54</sup> The trials drew attention to Neville's farming operations and made him a spokesperson for the results of the trials.

### Constructing Innovative Networks for Conservation Tillage: Summary and Conclusions

There are some differences, but many similarities, in the constructing of innovative networks in Christian County, Kentucky, and in the south-western and eastern Downs, Queensland. The differences arise primarily because of the priority of the Christian County networks and of the knowledge base available when the networks were established. There were differences with the U.S. case too in the role of both the local and global networks in the construction of local tillage frames and systems.

#### *Initiating the Local Innovative Network*

In Christian County, identification of the origin of the local innovative network is somewhat arbitrary. Did it begin when Harry Young, Jr., and Shirley Phillips began collaborating in herbicide trials in the late 1950s, or when Harry Young, Reeves Davie, and other local farmers began no-till trials in 1962? It is most clear that the networking evolved as these individuals pursued the construction of a new tillage and cropping frame. Successes and failures, new ideas, and new herbicides triggered successive rounds of collaboration, gradually cementing network relationships as the tillage and cropping frame expanded.

In Queensland, there was a similar evolution in the construction of local innovative networks beginning with the initial establishment of the MECs. The initiative in this case clearly lies with SCB officers and, compared with the Christian County network, the role was truncated. A stubble mulching frame existed, although poorly understood, and the purpose was to gain better understanding of the frame as well as to evaluate and develop appropriate machinery. As new technology (e.g., herbicides) became available, the local network expanded, but the initiative primarily remained with SCB officers.

### *Farmers' Role in the Local Network*

In Christian County, the most information anyone—farmers or professional advisors—had was “notions” that herbicides would work or that crops could be planted in untilled ground. Advisors were gaining information from farmers’ trials as much as from distant experiments. The process of tillage frame development was led substantially by the problems encountered by farmers.

On the western Downs, the MECs were formed by SCB administrators primarily to develop information that SCB officers could use in “training” farmers. Under Lindzey Ward, however, the farmers transformed the committee into an innovative network to develop their own new conservation tillage systems.

### *The Global Connection*

In Kentucky, the chance linkage of Harry Young, Jr., with Webb and McKibben introduced the notion of no-tillage into the emergent local innovative system in Christian County. Subsequently, as the latter attempted to solve problems of weed control and planting, they initiated linkages with chemical and machinery companies, which enabled them to construct satisfactory solutions. As will become more evident as the spread of no-till culture is examined in later chapters, the activities and successes of the local innovative system stimulated the global system to advance understanding of conservation cropping.

In Queensland, representatives of global systems played both passive and active roles vis-à-vis the local networks. Initially, SCB officers sought linkages with the global systems in the United States to initiate the process of stubble mulch frame construction. Later, global chemical companies played an active role in energizing local innovative networks to construct reduced tillage systems. Local networks on the Downs also induced local machinery companies to develop better stubble-handling cultivators and planters. In both countries, therefore, the flow of influence between the local and global systems was reciprocal.

### *On Innovation, Reinvention, and Diffusion*

Some might be inclined to argue that the development of stubble mulching in Australia, and later zero-tillage, are merely instances of successful diffusion, or transfer, of innovations in the conventional sense. Such a conclusion, of course, would primarily attribute the new Queensland tillage systems to the new machines and the information transferred from the United States. This argument, however, overlooks the

creative contributions of the Queensland farmers and their advisors, or it merely credits the efforts as adaptive reinventions.

A diffusion paradigm does not fit the data because the flow of information from the United States to Queensland advisors and farmers mainly consisted of notions about tillage and technical scripts for specific implements (later for specific herbicides). Due to differences in climate, soils, and weed regimes, Queensland farmers and their advisors had to construct reduced tillage and zero-tillage systems for a new range of crops. In other words, it was the new tillage and cropping systems, not the machines and technical scripts, that determined the success of conservation cropping on the Downs. In other words, the tillage frame that was transferred substantially failed while that constructed in Queensland succeeded.

The information that conservation "change agents" (e.g., Kamel and Ward) were able to transmit to farmers, moreover, was limited relative to that which the network created and fed back to the change agents. Instead of information dissemination, the principal function of the network in each case was knowledge creation of a new tillage and cropping system.

What the Queensland soil conservation officers primarily gained from the United States were tools and ideas with which to begin work. Official reports (SCB 1976, 5-6) make plain that the machinery testing program in the early 1970s "flourished, despite some early problems, due to the enthusiasm of a small group of farmers." In other words, if not for the network's creative interest in continuing the course of tillage system development, the program would have been abandoned as a failure.

The important, creative role of farmers in these networks can be seen in the contrasting success and failure of the Plains and Brigalow networks (MECs), respectively, with whom Lindzey Ward was involved. As Ronnfeldt (1988a), a key member of the Plains MEC puts it: "We took the approach. We are the farmers. We'll develop the machinery we need and tell the manufacturers what we need, in consultation with the DPI experts." Although the idea base with which these farmers started was considerably larger than what the Christian County, Kentucky, farmers had to start with, the creative role played by the local networks in the eventual successful construction of the conservation cropping frame was no less profound.

## Notes

1. The latter situation exists when the central, or hub, individual in a homophilious group with strong internal ties is linked to the central individual

in a different homophilious group (Granovetter 1973, 1982; Rogers 1983; Rogers and Kincaid 1981; Valente 1995).

2. In his "proposed model" of the "adoption-diffusion process for conservation technologies," Nowak argues that K-U-A (knowledge, utilization, adaption) "is influenced by a number of ecological, personal, technological, economic, and community factors" (Nowak 1984, 219). The technological, economic, and some of the community factors are global in nature.

3. During the 1950s and 1960s, funding for the Cooperative Extension Service expanded substantially, and the number of agricultural programs increased accordingly. For example, between 1950 and 1965, total funding for the Kentucky Cooperative Extension Service increased more than 2.7 times. (See Cooperative Extension Service, *1950 Annual Report* and the *1965 Annual Report*.)

4. Davie (1996). Membership on the Extension Council is gained by election. The members of the Extension Board are appointed by the County Judge executive.

5. In Kentucky, the campaign to raise corn yields had started in 1946 with the Corn Derby and the slogan "40 by 60" (i.e., achieve a statewide average of forty bushels per acre by 1960). Actually, this target was much too low, being reached in 1948 (Smith 1981). But, the target was quickly raised.

6. During the latter part of the 1950s, research on growing row crops under minimum or no-tillage conditions was being conducted in nearly all midwestern states from Iowa to Ohio, Virginia, and North Carolina (Shear 1985; van Es and Notier 1988).

7. In 1959, custom operators in Kentucky were charging \$1.00 to \$1.50 per acre for cultivation and \$1.50 to \$2.50 per acre for spraying 2,4-D ("Weed Control in Corn" by S. H. Phillips in *The Progressive Farmer*, Vol. 74, No. 6, June 1959, p. 31). Reported costs in Iowa were \$0.85 per acre with two-row cultivator and \$0.70 per acre with four-row cultivator, compared to \$2.00 an hour for tractor and trailer-type boom, not including the chemical (*Wallaces Farmer*, Vol. 84, April 4, 1959, p. 62). Hoeing, which was the only means of eliminating weeds in the row, was very expensive and time consuming. This made in-row weed control a very high priority. See "The Herbicides Make Good Hoe Hands" by W. C. Lasiter (*The Progressive Farmer*, Vol. 75, No. 3, March 1960, pp. 46, 51).

8. See "Weed Control in Corn" by S. H. Phillips in *The Progressive Farmer* (Vol. 74, No. 6, June 1959, p. 31); "You Need not Have Weedy Corn" by Pete Head in *The Progressive Farmer* (Vol. 76, No. 4, April 1961, p. 63).

9. *Wallaces Farmer* (Vol. 84, April 4, 1959, p. 35) indicated that 67 percent of Iowa farmers in 1959, up from 45 percent in 1955, were planning to use some form of chemical weed control in corn. Band spraying of preemergent herbicides were most highly recommended.

10. "Cultivators Stay in the Barn" by Harry M. Young, Jr., *The Progressive Farmer* (Vol 76, No. 11, November 1961, p. 17).

11. The debate over the comparative advantage of fall versus spring plowing for corn was settled during the 1950s with the yield advantage going to plowing in the fall (*Wallaces Farmer*, Vol. 71, April 6, 1946, p. 358; Vol. 76, August 18, 1951,



p. 20; Vol. 78, October 3, 1953, p. 18; Vol. 83, March 15, 1958). But, the price was greater erosion (*Wallaces Farmer*, Vol. 70, September 1, 1945, p. 593).

Articles in *Wallaces Farmer* (Vol. 84, April 18, 1959, p. 13) and *The Progressive Farmer* (Vol. 77, April 1962, p. 45) advised farmers to use adapted, full-season hybrids; fertilize according to soil test; prepare a good seedbed; plant early (i.e., before May 25); seed at 14,000 to 16,000 plants per acre; and control weeds. For eighty to 100 bushels of corn per acre, Iowa farmers could expect to use 40 to 80 pounds of nitrogen, Kentucky farmers eighty to 125 pounds. Whereas Kentucky farmers might use 70 to 80 pounds of phosphate and 80 to 120 pounds of potash, Iowa farmers needed less than one-half that amount. Yields of corn planted after May 25 decline about a half-bushel per acre per day that planting is delayed.

12. "Do Corn Belt Farmers Work the Soil Too Much?" in *Wallaces Farmer* (Vol. 80, May 21, 1955, p. 12) cites opinions of soil scientists; "Your Soil: Is It What It Used to Be?" by Harold Benford and Ed Wilborn in *The Progressive Farmer* (Vol. 73, No. 8, August 1958, p. 15) notes the "soil packing by farm equipment, animals, and water." Plowing at same depth each year creates plowsole and "Every trip over a field with tractor and equipment packs the soil (p. 15)."

13. In the late 1950s and early 1960s, articles in farm papers began stressing the advantages of "minimum tillage" and the use of herbicides in cutting expenses, reducing time spent in field operations, and controlling weeds. See *Wallaces Farmer*, Vol. 83, May 3, 1958, p. 20; Vol. 84, March 7, 1959, p. 42, and May 2, 1959, p. 66; *The Progressive Farmer*, Vol. 75, March 1960, pp. 46, 51; Vol. 76, April 1961, pp. 62–63, 136.

"Plow, Plant and Forget It!" headlined a 1963 report in the *Kentucky Farmer* (Vol. 99, March 1963) of the successful use since 1956 of plow-plant technique by John B. Byers on his ninety-six-acre Mercer County, Kentucky, farm. Two days before planning to plant corn, Byers plows under the cover crop and fertilizer needed, then corn is planted in tractor-wheel tracks. Byers believes (*Kentucky Farmer*, Vol. 101, April 1965, p. 12) this system saves cultivation costs, improves soil tilth, prevents erosion on hillsides, and saves moisture compared to conventional tillage. But, Byers admits that plow-plant increases the difficulty of timely planting and of controlling grasses in continuous cropping.

14. "What's Available in Mulch Planters" in *The Progressive Farmer* (Vol. 76, No. 4, April 1961, p. 136) briefly describes and pictures six "mulch planters" with lister or rotary moldboard openers.

15. "Minimum Tillage Saves \$3 to \$6" in *The Prairie Farmer* (Vol. 131, March 7, 1959, p. 71), according to research by Clarence Hansen, Michigan State University agricultural engineer. "Minimum Tillage Gains Favor" by Carl Eiche in *The Prairie Farmer* (Vol. 133, March 4, 1961, p. 11): "There is evidence of a real swing to minimum tillage this year" in Indiana—perhaps five times as many as in 1959; "Cut Expenses with Minimum Tillage" in *Wallaces Farmer* (Vol. 84, March 7, 1959, p. 42) "Two Linn County, Iowa, farmers are strong advocates of minimum tillage." Purdue researchers report wheel-track planting saves \$5 per acre over conventional tillage. "Plow, Plant and Forget It" in *Kentucky Farmer* (Vol. 99, March 1963): John Byers, Mercer County farmer, has been using wheel-track



planting since 1956, and corn in 1962 averaged 103 bushels per acre. "Wheel-Track Corn Planting" in *The Progressive Farmer* (Vol. 77, No. 3, March 1962, p. 22c) briefly reports favorable experiences of several Kentucky farmers in growing corn using the wheel-track method: Bascum Smith, W. T. Stephens, and Kelley Bernard in Russell County; John Hancock, Union County; and John Byers, Mercer County.

16. *The Progressive Farmer* (Vol. 78, No. 1, January 1963, p. 57): "What farmers are asking: Why is wheel-track planting sometimes criticized in areas where soil permits this practice? Plowing must be done a day or two before wheel-track planting. Therefore, planting is often slowed down. Because of this, a four-row planter during one season covers fewer acres than if it were planting on conventionally prepared soil."

17. An extension circular on *Growing Corn in Kentucky* by S. H. Phillips and F. A. Loeffel (Lexington, KY: University of Kentucky Extension Circular 558, April 1963) included the following observation: "Land preparation for corn is being reduced each year, thus lowering the cost of growing the crop and reducing the destruction of the physical condition of the soil. Wheel-track planting is a revolutionary practice in soil preparation. . . . Planting corn in the tractor tracks of newly plowed ground has attracted wide interest and is being used by more and more farmers."

18. Annual reports of the Director of the Kentucky Experiment Station in the 1960s indicate that weed scientists were conducting studies of the effectiveness of different herbicides; corn breeders were developing improved corn varieties, and soil chemists were studying the relation between fertilizer and corn yields, but no-tillage did not become a subject of research until 1966.

19. Harry Young carried out official extension trials on chemical weed control in corn from 1963 to 1968, and later in soybeans from 1967 to 1972 (Davie 1996). Three pounds of Atrazine per acre was sufficient to give "good grass and weed control" (Head 1963).

20. "Southern farmers who have tried it [no-till corn] report good results. In fact, 'no-plow' corn out yielded corn planted on prepared seedbeds on two Kentucky farms last year. . . . Last year . . . zero-tillage corn out yielded regular tilled corn at Dixon Springs Agricultural Center in southern Illinois" (Head 1965).

21. Information on ways to modify planters was increasingly available (Johnson 1966). However, planter modification was a challenge to managerial ingenuity (Carlson and Dillman 1988).

22. In 1964, the Kentucky Cooperative Extension Service began to organize extension programs on an area basis (Seay 1964). The objective was to enable each of the sixteen multicounty extension areas of the state to plan annual programs best-suited to its area. The Agricultural Agent in each county was responsible for coordinating extension programs in his county and had area-specialist responsibility as well (e.g., for field crops, farm management, horticultural crops, tobacco, beef cattle, hogs, etc). If farmers in any of the Pennyryle counties wanted a program on a relevant farm management topic, Reeves Davie was responsible for getting together the information and presenting the program.

23. For elaboration see "Mobilizing the Global Network" below.

24. Coincidentally, in 1967, T. S. Speight, an R. J. Reynolds agronomist, tested double-cropped soybeans at Merry Hill, North Carolina (Phillips and Young 1973; van Es and Notier 1988)

25. Harry Young collaborated with Shirley Phillips in official soybean variety trials from 1968 through 1970, and with Jim Herron on chemical weed control trials in soybeans from 1967 to 1972 (Davie 1996).

26. Davie (1996) estimates that more than 13,000 persons had visited Harry Young's farm to view no-till crop since 1962.

27. "Herbicide Combinations for Better Weed Control and Less Residue in Soil," and "Herbicides for Zero-Tillage of Corn in Killed Bluegrass Sod," pp. 19 and 20, respectively, in Kentucky Agricultural Experiment Station (1967).

28. A substantial increase in studies of no-tillage cropping and related soil management issues is reported in Kentucky Agricultural Experiment Station (1970).

The mobilization of agricultural scientists at the University of Kentucky to study no-tillage as well as the growth of the science of no-tillage crop production is reflected in Phillips et al. (1978) and Phillips and Phillips (1984).

29. See *Proceedings of No-Tillage Symposium*, 1972; *Conservation Tillage, Proceedings of a National Conference*, 1973; *Proceedings, No-Tillage Research Conference*, 1974.

30. After 1971, sales of Allis Chalmers planters in Christian County stabilized at about twenty planters each year (Choi 1981).

31. "It is to the credit of many officers of the Soil Conservation Branch, including J. E. Ladewig, J. Rosser, G. L. Swartz, A. F. Skinner, R. F. S. Kelsey and M. H. Roberts, that this Department continued to keep abreast of the latest overseas developments in stubble mulching techniques and equipment. The activities of these officers plus the enthusiasm of practicing farmers, such as Mr. H. H. Tod of "Popular Farm," Jondaryan, and the support of the late Mr. J. Jones (formerly Secretary of the Council of Agriculture) (Qld.) finally culminated in a visit to the U.S.A. by Messrs. H. H. Tod and Swartz" (SCB 1976).

32. The items of equipment were a LZ 1410 B Lister Drill, 100 Series Chisel Plough, 450 Series Chisel Plough, and an 830 (800) Series Rod Weeder (SCB 1976). As a result of representations to the Commonwealth Minister for Customs and Excise by the Council of Agriculture (Qld.), the equipment was imported on a duty free basis.

33. "Initial members were J. Jones, Secretary, Council of Agriculture, G. L. Swartz, Supervisor, T. R. Kamel, Secretary and Programme Co-Ordinator, I. Grevis-James, Agricultural Engineer, H. H. Tod and V. C. Roberts, farmers, W. E. Dudley and N. Monday, Assistant Manager and Territory Manager, John Deere Australia, Ltd." (SCB 1976, p. 5.6). Inasmuch as the committee was not formalized, attendance at meetings, apart from a small core (Swartz, Tod, Grevis-James, and Kamel) of regular attendees, depended on the interests of individual members in the particular agenda.

34. The farmers were "M. Fletcher, N. Redding, H. E. Ritter of Mt. Tyson, R. B. Teakle and H. H. Tod of Jondaryan, and W. Martin of Wyreema" (SCB 1976, p. 5.6), and their enthusiasm contributed to the success, in the long run,

of the testing program. The district officer primarily in charge of the MEC was Lindzey Ward (Ward 1988), but other district officers, including T. Kamel, and representatives of John Deere Australia, Ltd., also were involved.

35. In July 1977, the limit of the subsidy for machinery was raised to \$1,000 (Pauli 1978).

36. The MTC, renamed the Queensland MEC, was responsible for coordinating the activities of the other subcommittees. A fourth subcommittee—Brigalow MEC—was envisioned but never established.

37. Agricultural Branch officers involved in the machinery evaluation program were N. Delaney, J. Littler, J. Marley, and S. Walsh (SCB 1976).

38. In the early 1970s, the Napiers Bros. scarifier was a three-bar cultivator with 2-foot shanks and sweep-share points spaced either at 6 1/2 or 9 inches (Fountain 1988).

39. See Ronnfeldt, 1988b, chapter 7.

40. The benefits of farmer-led experimentation in adopting innovations is widely recognized (Tully 1966; Chambers et al. 1989).

41. Darwin Alexander and Max Middleton were MEC members who purchased blade plows. More than a decade later, Taylor, the farmer who bought a plow after the field demonstration, told L. Ward that the blade plow was the best implement he had ever purchased for his farm: "It's made us a lot of money" (Ward 1988).

42. Soil and field conditions were major factors. The blades had difficulty penetrating the hard clay soils, especially when the blade became a little dull. Weighting the plow helped solve this difficulty. Most farmers tended to operate the plow at the same depth, and this tended to create a plowsole that then had to be ripped with a chisel plow. One of the biggest problems was in maintaining proper sweep alignment when operating in recently developed fields with rocks or stumps. In this respect, a chisel plow was a more practical piece of equipment (Ward 1988).

43. Most similar to the Queensland environment are the black soil areas of southern Texas (Ward 1988).

44. The Surface Management Project was a collaborative project between the SCB and the Wheat Research Institute.

45. Extension activities were carried out on a regional and district basis. Although training, resource materials, press releases, and staff support were provided on a regional basis, field days, farm walks, and individual contacts were carried out on a district (multishire) basis. *Conservation Cropping: Darling Downs Extension Programme 1981–82*.

46. The others involved were Mack Howell, Brookstead Farm near Goondiwindi, and Colden at Westmar (Ward 1988).

47. The wet summer had another important consequence for the use of herbicides in general and Roundup in particular. Because of the wet weather, farmers were unable to cultivate the fallow to control weeds, which threatened to become unmanageable. This prompted many farmers to spray fallow with Roundup to control weeds, then cultivate fields prior to planting when fields became drier (Guthrie and Frazier 1988).

48. See Ronnfeldt (1988), Peterson (1988), and Bell (1988), chapter 7.

49. See Ronnfeldt, 1989b, chapter 7.

50. For example, see Newton, 1988b, chapter 7. "Ward (1988) pointed out that the use of zero-tillage technique spread widely in the Goondiwindi area following the trials on Howell's and Woods' farms in that area. Also see Woods (1988).

51. See chapter 7.

52. See Heard (1988), chapter 7.

53. Colin Bell, for example, obtained valuable information from Neville Ronnfeldt. He sought advice on soils from the Hermitage research center and information about fertilizer requirements from Elders Company. The latter sponsored him on a 1985 trip to the United States to see the conservation tillage systems being used in the Great Plains (Bell 1988). Observations on the trip were reported to the Queensland Grain Growers.

54. The trial consisted of barley, followed by mung beans and sorghum. Drought and birds damaged the validity of the trials.

# 6

## Social Construction of New Tillage and Cropping Systems in the United States

*The landscape of any farm is the owner's portrait of himself.*

—Aldo Leopold (1939, 316)

As the sixth decade of the twentieth century unfolded, some grain growers on the Great Plains were using a tillage system—stubble mulching—that enabled them to save soil and moisture and reduce tillage costs while maintaining or increasing yields (McCalla et al. 1962). There were, however, several important constraints. In wetter areas, the new tillage system exacted a penalty in somewhat smaller yields and poorer grain quality.<sup>1</sup> Weeds, such as downy brome, which were difficult to control with herbicides, compelled farmers using a wheat-fallow rotation to revert to the use of sweeps as well as herbicides to control weeds in fallow. In parts of Nebraska and Kansas, farmers shifted to a system of “eco-farming”—a rotation of winter wheat and summer sorghum and the use of sweeps and herbicides to control weeds both in the crop and in fallow (Wicks 1986). Wheat growers had a tillage frame, which they continued to adapt, as they addressed emerging problems.

In the Midwest and South, however, despite mounting pressures to reduce soil erosion and plow-culture labor costs by reducing tillage and substituting herbicides, a satisfactory conservation tillage system for row crops had not been developed. (See chapter 4.) To save soil, Federal Soil Bank programs encouraged farmers to expand grass lands and increase cattle numbers. This put downward pressure on cattle prices and made grain growing relatively more profitable.<sup>2</sup> Farmers thus had an economic incentive to keep their nonconservation reserve land in crop production and to minimize the time it was in a soil-saving grass or legume rotation.<sup>3</sup>

Farmers were caught in a dilemma. On the one hand, the motivation to expand output of profitable crops and reduce input costs was intense because the margin between farm costs and prices was narrowing, and

farm incomes, relative to nonfarm incomes, were declining.<sup>4</sup> For farmers, especially in Kentucky, it meant declining interest in two of the culturally and economically dominant farming systems i.e., beef cattle and dairying.<sup>5</sup> On the other hand, the expansion of cropping meant abandoning a long-accepted, market-risk-minimizing, mixed-crop and live-stock farming system that kept land in grasses and legumes five years out of seven. Grain growing magnified the problem of controlling erosion on cropland. As pointed out in chapter 5, it prompted researchers, profit and conservation-minded farmers, and farm advisors to experiment with the substitution of herbicides for tillage operations.

In this chapter, we present seven case studies of Kentucky and Iowa farmers in local innovative systems constructing new farming and tillage systems. The cases display the adaptive innovation of different tillage strategies for a variety of farming systems and land types. Each case is presented schematically to indicate the *action-learning* trials undertaken by the farmer as he progressively abandoned conventional plow culture and constructed a new tillage system of his own design, the critical "moment" of decision at each step, and the problem(s) as the farmer perceived it. (Refer to fig. 2.5.) Cases of Australian farmers constructing appropriate tillage and cropping systems are presented in chapter 7.

The first trials in Kentucky of no-tillage or zero-tillage, however, were made by Harry Young, Jr., and his brother in Christian County, Kentucky.

### Harry Young, Jr., and the Social Construction of No-Tillage and a New Cropping System<sup>6</sup>

As a result of his training and interest in farm management, Harry Young was conscious of the cost-price squeeze and the need to reduce labor costs and increase productivity of land. Moreover, he was familiar with developments in soil management and knew that unprotected soil could erode severely (Fig. 6.1). Consequently, he began in 1954 to put these ideas into practice when he started farming in partnership with his father and brother. To support the principal economic enterprises of beef cattle and tobacco raising, Young established a forage-cropping rotation to help build and conserve his soil resources. The rotation followed standard recommendations of the Soil Conservation Service: Each field was kept in grass or legume sod 3 or 4 years out of 7.<sup>7</sup>

#### *Initial Action-Learning*

Pressed to save labor time, Young decided to try using 2,4-D (and other herbicides when they became available) to reduce the time spent in hoeing and cultivation. He found, as other corn belt farmers and weed specialists were then recommending,<sup>8</sup> that an application of 2,4-D at plant-

ing time stopped the emergence of many weeds and that satisfactory weed control could be obtained with only one cultivation for grassy weeds followed by another application of 2,4-D at layby time. The increased labor efficiency gave him time for other farm chores and convinced him that herbicides could be a helpful tool in weed control. But, 2,4-D was ineffective against grasses, and Young continued to prepare plant beds, to plant, and to cultivate corn and other grain crops in the conventional manner.

### *Dissonance and Action-Learning*

By delaying seedbed preparation and preventing cultivation of newly emerging crops, unusually wet springs were a serious problem for yield-conscious, western Kentucky corn producers. They knew that the yields of corn planted after May 15 decline progressively and that failure to cultivate weeds also hurt yields. A wet spring in the late 1950s confronted Young and other Christian County farmers with just this dilemma. The availability of Dalapon, which controlled some grassy weeds, however, provided an opportunity of avoiding further loss from a weedy field, and several farmers decided to try substituting herbicide treatments for cultivation (van Es and Notier 1988). The strategy worked well enough the first year that several tried it the following year. But, Dalapon did not control several kinds of grassy weeds, notably john-



Figure 6.1. Erosion in Kentucky.

songrass, which became more troublesome. Consequently, despite the benefits, Harry Young abandoned this attempt to substitute herbicide treatment for cultivation.

These experiences, however, did convince Harry Young that chemical control of weeds could save time and might be worthwhile if a better herbicide became available. Thus, his interest in herbicide substitution was rekindled when he heard about Atrazine, a new herbicide for grassy and broadleaf weeds. Even though Atrazine was untested in the area, and no one knew for sure at what rate it should be applied, Young decided in 1961 to try it. After plowing and disking the field, Young planted corn and immediately broadcast Atrazine at the rate of 2 1/2 pounds per acre (Young 1961). A comparison of weed survival in fields with and without a follow-up cultivation convinced Young that the latter was a waste of time and tractor fuel. Atrazine broadcast and 2,4-D gave better weed control and saved time for other farm tasks, and he decided to use this strategy in the future. He had constructed a new tillage system that satisfactorily substituted herbicides for several post-plant tillage operations.

### *Second Dissonant Event*

As he was concluding that he could control weeds effectively with herbicides alone, Harry Young heard through Reeves Davie (Extension Agent) about a trip being planned for early August to see livestock experiments and field plots at Dixon Springs, Illinois.<sup>9</sup> Young went on the trip, and one of George E. McKibben's experimental plots especially attracted his attention. It was an experiment in growing corn without tillage in killed grass sod (Davie 1996; van Es and Notier 1988). Although the plot was not replicated due to the breakdown of the shop-built planter, it was apparent that the corn in the plot would yield very well because the ears were already well formed. Harry was interested because of his recent experience in using Atrazine to reduce cultivation. Later that fall, he wrote to Superintendent Robert J. Webb at the Dixon Springs Experiment Station for the plot yield data. The yield in the no-till plot was higher than in several of the conventionally tilled plots. The possibility of completely eliminating tillage excited Harry Young, and he decided to set up a trial in 1962.

### *Second Action-Learning Cycle: Construction of a New Tillage System*

Harry Young and his brother chose 0.7 acre on the side of the road, which had been seeded with barley and lespedeza the previous year, for the no-till trial. Harry Young applied Atrazine to kill the sod and any weeds. He planted corn on April 25 in the killed sod using an old



planter that he modified for the purpose by mounting on it a 50-gallon drum filled with water to force the planting shear through the stubble and 1.5 inches into the unplowed, red limestone soil. Although this opened a slot into which the seed was dropped, many of the seeds were left exposed because the planter wheels did not press the soil around them. Young solved this problem by running the wheels of his tractor over the rows to compress the soil. All around was corn planted the conventional way. Although the yield of the no-till corn was satisfactory, the heavy preplant Atrazine application damaged the lespedeza, which they planted after corn harvest.

However, the initial success of the no-till trial aroused the interest of local farmers, extension workers, and reporters for regional farm papers.<sup>10</sup> This encouraged Harry and his brother to begin formal experimentation to determine how much Atrazine was necessary to kill sod and control weeds. Hopefully, they could minimize residual damage by reducing the application of Atrazine.

For the 1963 season, they marked off three plots on a 1.2-acre area. Atrazine was broadcast at three different rates—5, 3, and 2 pounds per acre—to kill the lespedeza and weeds. Later that month, the equivalent of 800 pounds of 15-10-5 fertilizer was broadcast on the field. The 5- and 3-pound (but not the 2 pound) applications of Atrazine killed the sod and controlled the weeds. In August 1963, the County Agricultural Agent organized a meeting at Young's farm of farmers interested in seeing the no-till corn trials on Young's and neighboring farms, who also had begun trying no-till corn. Grain yields from Young's no-till plots that fall exceeded yields in the conventionally tilled field.

For the next 6 years, Harry Young, Jr., continued to make comparisons of no-till and conventionally-tilled corn (Phillips and Young 1973). In the fall of 1963 and each of the following two years, the cropping system consisted of no-till corn followed by barley and lespedeza using a trial system of reduced tillage. Corn was no-tilled into lespedeza sod. After corn harvest, the field was double disced, and barley and lespedeza seed were broadcast and disced in. If the corn harvest was delayed, barley and lespedeza were aerial seeded in the standing corn. The barley was harvested in June of the next year, and the lespedeza seed harvested in the fall. In 1966, Young switched from barley to wheat and lespedeza as a more profitable alternative (Fig. 6.2).

### *Third Sequence in Action-Learning: A New Tillage and Cropping System*

As a result of conversations with Reeves Davie, George McKibben and others in 1966 (Davie 1996), Harry Young decided in 1967 to take advan-



Figure 6.2. No-tilling in Kentucky.

tage of the time saving in no-till cropping to try changing their cropping system again. Immediately after the wheat harvest, soybeans were no-tilled into the wheat stubble. Although the double cropping of soybeans after wheat or barley harvest was not a new practice in the region, it was rarely tried locally. To be successful, second-crop beans had to be planted at least by July 1, and the further in advance of that date the better. Planting delays caused by plowing and discing, or by burning wheat straw and discing, to prepare a plant bed as well as the loss of moisture through this process made double-crop beans a highly risky venture.<sup>11</sup> Harry Young recognized that both of these constraints were minimized by no-till planting.

But, planting soybeans in wheat stubble on a large scale was not possible without an efficient no-till planter. Fortunately, Allis-Chalmers had just begun manufacturing a no-till planter, and with the assistance of the county agricultural extension agent, Young was able to purchase one (Davie 1996).<sup>12</sup> The no-till planter, of course, was an important improvement in planting corn and soybeans in untilled ground—insuring proper seed placement and coverage and a good stand. The success of the trial and demonstration of the system to large numbers of other

farmers in the area persuaded many to begin constructing similar tillage and farming systems.<sup>13</sup>

The rotation of no-till corn followed by wheat and no-till soybeans—giving three crops in two years—was repeated in 1968 and 1969. Thereafter, the Young brothers shifted entirely to no-till corn and soybeans and minimum tillage wheat.

Careful records were kept during the course of the trials. Although yields of no-till corn and conventionally tilled corn varied, no-till corn yields over the 8-year period averaged higher than those of the check plots. But, of greater importance, the Youngs achieved 150 percent efficiency in the use of each tillable acre, and by the mid-1970s were alternating 625 acres of soybeans and corn; and, after the corn harvest, barley and fertilizer would be spread and disced in on one-fourth of the acreage and wheat and fertilizer on the remainder. Residues from the barley or wheat and soybean crops were left to protect the soil until corn planting the following spring.<sup>14</sup> The increase in both land and labor efficiency, and the expansion of acres under high-valued commercial crops, substantially increased the profitability of the farming operation.<sup>15</sup>

#### *Further Adaptive-Learning with the New Tillage and Cropping System*

All during the 8-year trial period, the Youngs had wrestled with weed control and planting problems. Their decisions were questioned at every step. Time after time, they had fended off “it-will-not-work” comments of skeptics. Only six months prior to acting on the decision to try no-tillage corn in March 1962, readers of *The Progressive Farmer* (Vol. 76, October 1961, p. 48) were reminded of a fundamental tenet of plow culture: Deep plowing of crop residue and a legume rotation control myriad crop diseases and insect pests, making it the most profitable tillage system. The Youngs themselves had once subscribed to this belief, but Harry Young had read Faulkner’s *Plowman’s Folly* and Bromfield’s *Pleasant Valley*, and, he was emboldened to try his own experiments, which convinced him that leaving the residues of cover crops on the surface, as the no-till advocates recommended, was as important to maintaining soil structure and fertility as turning under legume cover crops. In their first no-till corn crop, of course, they had not abandoned the idea of a long rotation with legumes or grasses, which they later modified.

But, an even weightier risk was the crop loss due to the increase in insects and disease bred in the altered microecology at the soil surface. The Youngs had to construct a system with chemical insecticides and fungicides and crop rotation that would satisfactorily control insect pests and diseases that occurred due to their new tillage and cropping system.<sup>16</sup>

Using herbicide and insecticide sprays effectively and efficiently required developmental learning of a wide range of complex skills. Some were practical and economic (for example, the importance of having a second tractor on which to keep spray equipment mounted for several months during spring and summer, thereby saving time and facilitating rapid shifting in spray tasks).<sup>17</sup> Some required experimental testing and evaluation. From 1962 to 1968, herbicide applications on the no-till corn plots were part of the Cooperative Extension Service state herbicide trials. Similarly, from 1967 to 1972, the Youngs cooperated with the Extension Service in official herbicide trials on weed control in soybeans. Through this collaboration, they became expert in the use of herbicides (for example, the effective application rate of Atrazine to kill sod and weeds versus rates for plowed ground; the effect of soil type, moisture, and amount of residue on herbicide effectiveness; or when and how best to apply herbicides).<sup>18</sup> Atrazine was highly effective against a broad spectrum of grasses and weeds and had a relatively long residual, but the heavy applications of Atrazine needed to kill sod and its lengthy residual often damaged the small-grain crop planted after harvesting the corn crop.

The discovery of Paraquat, which was an effective knock-down herbicide developed in 1958, enabled them to solve this problem. Initially, Paraquat was used in pasture renovation and, in western states in orchards, but McKibben used Paraquat in a no-till trial in 1963. On a return visit to Dixon Springs, Harry Young, Jr., saw the successful trial and persuaded several other Christian County farmers to join him in ordering a substantial quantity of the product for their use in 1964 (Young 1999; Davie 1999).<sup>19</sup> Subsequent, Agricultural Experiment Station trials demonstrated that farmers could reduce Atrazine application rates by one-half.<sup>20</sup>

Use of herbicides led to weed succession problems (e.g., giant foxtail and johnsongrass, which required new rotations or the development of new herbicide combinations or both).<sup>21</sup> Other problems required ingenuity in modifying and using equipment to apply chemicals at the required rate (for example, development and calibration of spray equipment).<sup>22</sup> Initially, Harry Young was convinced that high rates of water at high pressure was the most effective technique.<sup>23</sup> But, as crop acreage and herbicide use expanded the problem of supplying large quantities of water compelled them, as well as other local farmers, to begin using lower rates of water per acre. New herbicides also made possible lower application rates. The acquisition and use of protective equipment and development of skills in carefully following instructions in handling highly toxic chemicals and in properly cleaning equipment required

both commitment and discipline.<sup>24</sup> Harry Young, Jr., became an authority on this most difficult task—the proper use of chemical herbicides.<sup>25</sup>

In 1966 and 1967, the Youngs kept detailed records of machinery and man-hour requirements for producing corn by no-till and conventional methods. Their data indicated that an acre of corn could be produced by no-tillage with less than one-half as many man-hours as with conventional methods. Moreover, it required less time to produce an acre of no-till corn with a three-plow tractor than one acre conventionally with a four-plow tractor. In other words, a farmer could save on both time and machinery costs in producing no-till corn (Fig. 6.3 and Fig. 6.4).

Determination of satisfactory application of fertilizer presented another set of issues that had to be worked out through experience and in consultation with researchers over a period of several years (Phillips and Young 1973). It was quickly discovered that, with a surface mulch, corn seemed to require greater amounts of nitrogen. How much, in what form, and how applied were issues that had to be resolved. Similar questions had to be answered for phosphorous and potash. These issues occupied the interests of soil chemists for many years (Thomas and Frye 1984). Answers to questions concerning when and how to apply fertilizers had to be developed with consideration of the equipment available and/or the possibilities of modifying equipment to permit efficient application.



Figure 6.3. No-till soybeans, Harry Young, Jr., farm, 1983.



Figure 6.4. No-till corn, Harry Young, Jr., farm, 1983.

Starting with the weighting of the conventional planter to enable it to plant in killed sod, the Youngs periodically modified their planters and spray equipment to improve the effectiveness or efficiency. From E. C. Martin, a neighbor, they adopted the idea of using the hydraulic power of the front-mounted cultivator on a row-crop tractor to mount a disc to cut a trench for the planting shear to follow in planting seed. Even the Allis-Chalmers no-till planter was modified by placing a straight coulter in front of the fluted coulter to cut through heavy crop residues. Development of equipment to apply herbicides as well as fertilizers and plant in a single pass over the field required construction of mounts for spray drums, hoses, nozzles, pumps, and metering devices.

Over a ten-year period—1962 to 1971—Harry Young, Jr., networking with George McKibben, Shirley Phillips, and others, constructed a new tillage frame and an operational tillage and cropping system.<sup>26</sup> The system of corn followed by wheat and double-cropped soybeans enabled Harry Young in 1973 to raise 1,650 acres of crops on 1,100 acres of cropland. For the Youngs, it was a highly efficient, effective, and profitable system.

Their success, and Harry Young's enthusiasm, encouraged many other farmers to construct similar systems for themselves. In 1973, he argued that farmers were accepting no-tillage cropping because it pro-



vided them “more net income from lower operating costs and higher volume . . . [with] conservation of soil and water . . . and pollution advantages” (Young 1972) as it had for him, and he was convinced that no-tillage would continue to expand for these reasons. It has done so; however, Harry Young underestimated the difficulty other farmers would have in successfully adopting his “simple system,” as he put it. That is, the Youngs and their farm were central components of their system, and other farmers quickly discovered that they, their farms, and their local environments were central components to their own tillage systems. Interested farmers could use the tillage-cropping frame, but not necessarily the specific practices or techniques. Each farmer had to reconstruct a tillage and cropping system, which he could manage successfully on his own farm, as well as learn new technical skills. Finally, although by 1971 Harry Young, Jr., had a complete no-tillage system, it was not a finished system because there was still much adaptive learning with respect to operating the system under different weather, soil, weed, and economic conditions. The building of the agricultural science of no-tillage was just beginning and would occupy the interest of scientists for more than three decades. See chapters 8 and 9.

### The Dixons and the Reconstruction of No-Tillage<sup>27</sup>

Davis Dixon grew up on a farm only 6 miles from his present residence, located on part of the 1,700 acres he farms with son Kirk in Hickman County, Kentucky. After graduating with a major in agriculture from Murray State in 1951, Davis began part-time farming on sixty acres while teaching agriculture in a federally supported vocational agriculture program for World War II veterans. In 1953, Davis began working as a salesman for the J. I. Case Company. During the next 20 years, he was promoted from salesman to district sales manager while continuing to farm part-time. Initially, he had a small cow-calf operation. Beef cattle, pasture, and forage crops suited two aims. Raising beef cattle required relatively little maintenance time, and growing forage crops suited his interest in soil conservation. But, as he acquired more land, he decided to try cropping and producing hogs. In 1966, Davis raised his first corn crop, using conventional tillage. For the next 3 years, Davis Dixon continued plowing, disking, and planting a small acreage into crops of corn, wheat, soybeans and feeding hogs and beef cattle.

#### *Initial Dissonant Event*

In the spring of 1970, Davis and his 18-year-old son Kirk plowed and disced a sloping, seventy-five-acre field to plant soybeans. In Davis

Dixon's (Dixon and Dixon 1992) words, "The field was in mouse-track shape." In other words, the soil was so finely tilled and smooth that one could follow the footprints of a mouse across the field. As they started the planting operation, they noticed a cloud on the horizon but had heard there was only a 15 to 20 percent chance of rain and thought little of it. Before they had made a round trip with the planter, however, the rain had started to fall; before they could get out of the field, it was raining hard, and in their words, "Before we got home it was a flood" (Dixon and Dixon 1992). Three to 4 inches of rain fell in a little more than an hour, an intensity they had not experienced before.

When Davis and Kirk drove to the field the next day, they were stunned. Much of the topsoil from their beautifully tilled field had been washed down the hill, out of the field and over the road. Although they reworked the field and planted soybeans, they made up their minds then that this could not be allowed to happen again. Davis Dixon had read about the soil-saving benefits of no-tillage. Kirk Dixon had heard about no-tillage in his agronomy courses at the University of Kentucky. Both had seen trial attempts of no-till corn in killed wheat on neighboring farms. During the fall and winter, as they thought about what had happened, they decided that next year they would have to begin developing a new tillage system.

The decision to construct a no-tillage cropping system was cemented by the coincidental decision of Kirk Dixon that he wanted to farm when he finished college. Kirk's decision to farm meant that they should acquire more land so that both could farm full time, which Davis also wanted to do. They would begin cropping more extensively, and Kirk especially wanted to go to a no-tillage system, about which he was learning at the College of Agriculture, University of Kentucky.

Implementing this decision, however, presented a problem, which other farmers frequently claimed had kept them from trying no-tillage. The Dixons knew that they would have to replace their relatively new conventional J. I. Case planter with a no-till planter.

In retrospect, the economic cost of trading for a new planter, however, seems to them not to have been as great a barrier as the embarrassment and possible retribution arising from this display of disloyalty to his employer (J. I. Case), which the purchase of an Allis-Chalmers planter implied. Davis Dixon called his supervisor and discussed the problem. Although the supervisor was unhappy about the prospect of his district manager using an Allis-Chalmers planter, he approved the project saying that Davis could tell him and the Case Company what he thought about the A-C planter.



*First Steps in Action-Learning: Initial Failures in No-tilling*

The Dixons tried out their new A-C planter, planting soybeans as a second crop after wheat in the summer of 1971. To control weeds, they sprayed the field with Lasso—a pre-emergence annual grass and broadleaf weedicide—just before starting to plant. After they had planted one-half the field, however, they decided that there was not sufficient moisture and quit, hoping that it would rain in a few days. But, they soon became anxious because of the narrow planting window in June, and went back a couple of days later to plant the remainder of the field, planting the beans more deeply hoping there was sufficient moisture at that depth.

When the rain came two weeks later, they got a poor stand on the second half of the field. Meanwhile, much of the Lasso had become inactive and did not control the foxtail sprouting after the rain. At that time, no over-the-top, knock-down herbicide was available to control the foxtail, and as Davis Dixon (Dixon and Dixon 1992) puts it, “It looked like a foxtail field, but we thrashed them [sic] beans,” which averaged 20 bushels per acre.

The Dixons did not let this bad experience with Lasso, however, deter them from going to no-till. As Davis Dixon (Dixon and Dixon 1992) puts it, “We just wasn’t [sic] going to farm and have that much erosion.”

The next year—1972—they no-tilled corn into the wheat-soybean-foxtail residue. They got a good stand of corn, but the grass came up with the corn. Because Davis Dixon was still traveling as J. I. Case sales manager, they were not able to spray a pre-emergent herbicide at planting time but waited until the corn came up and hired a contractor to apply herbicide to control grasses and weeds. The contractor had a “truck sprayer with flood jet nozzles which . . . [looked pretty] going across the field, but didn’t do a real good job” of getting the spray down on, and killing, the emerging, tiny, foxtail grass (Dixon and Dixon 1992). Consequently, Davis and Kirk had to go back on the field with their own spray rig and apply sufficient atrazine to kill the foxtail. This saved the corn crop, but the extra cost for herbicide took most of the profit. The experience, however, helped convince them to spray at planting time.

Like other farmers, the Dixons were bedeviled by johnsongrass in corn. Unlike many others who gave up no-till corn because of this problem, however, they adopted a strategy of total eradication of johnsongrass. Kirk walked fields with a sprayer to spot-spray any shoots that were found. Now, of course, the new herbicides and continual watchfulness have virtually eliminated the johnsongrass problem.

*Next Steps in Action-Learning: Constructing Successful New Tillage and Cropping Systems*

During the years 1972 to 1974, Davis and Kirk Dixon constructed the grain-growing system that they have followed since—no-till corn followed by minimum-tilled wheat and double-crop, no-till soybeans. Only one-half of the soybeans, however, are double cropped. The other half are full-season beans no-tilled into cornstalks. The principal reason for splitting the soybeans between full-season and double crop after wheat was to spread the workload. That is, they did not have sufficient time after wheat harvest to plant the total soybean acreage desired.

As the Dixons were constructing a no-till system that worked for them, they began to appreciate the importance of laying down herbicide as they planted. It would save a trip over the field and enable them to avoid spray-skips, which allowed weeds to grow and spread. Thus, in 1977 they constructed a mechanical system to spray and plant in one pass. Also in 1977, the Dixons decided to adopt the narrow-row (20-inch) planting system for soybeans. The narrower rows enable beans to canopy quicker, thereby aiding weed control. To accomplish this, the Dixons purchased a new A-C planter but modified it by having the tool bar cut and hinged so that it would fold up for easier transportation.

*Recent Advances in Tillage System Construction*

The construction of a satisfactory conservation tillage cropping system has been an evolving, adaptive process. Some of the adaptations have been relatively simple; others have been more difficult. One of the problems, which had a relatively simple solution, was the discovery that they could not plant beans after beans (as they could corn after corn) because of soil nematodes. Thus, the Dixons modified the cropping system into a corn–wheat–double-crop soybeans–corn–full-season soybeans rotation. Another relatively minor problem was the soil disturbance created by the fluted coulter on the A-C planter, which exposed soil to erosion; when the Dixons began planting and applying herbicides in a single pass, they discovered that some of the seed was exposed to herbicide. At that point, they decided to switch planters and purchased a Kinze Maximerge, which uses John Deere planting units on a Kinze frame.

Planting full-season soybeans by no-tillage initially posed an economic problem because of the cost of knockdown herbicides suitable for soybeans. However, after a few years' trials, the Dixons learned how to use Roundup with the low-rate spray technology, which cut use of the active agent in half, making the no-tilling of soybeans in corn stalks or a killed rye cover crop economically practical.

Constructing a satisfactory no-tillage system for wheat has been a more difficult problem. Although the no-tillage system for soybeans and corn was quite satisfactory, they initially developed a reduced tillage system for wheat because they did not own or attempt to purchase a no-till grain drill, and tillage helped control several perennial vines and field mice. After corn harvest, the field was double-disked twice before seeding wheat.

In the mid-1980s the Dixons purchased a no-till drill, which they now use to plant rye cover crops. In the mid-1990s, they began no-tilling about 65 percent of their wheat. But, they still minimum till the remainder of their wheat because of inconsistent yields of no-till wheat, and because perennial vines and field mice are more easily controlled with limited tillage.

For the Dixons, the problem of no-tillage weed control has been the most persistent. The failures and new adaptive tactics have been many. Several examples highlight the difficulties. Using information from Monsanto and trial experience over several years, the Dixons developed a low-rate spray technique. They started out using 40 gallons of water (and chemical) per acre as the Extension Service recommended. But, 1,000 acres at 40 gallons per acre requires a lot of water. They began trying to use less water, cutting back to 30 gallons, then 25, 20, 15, and now 10 gallons per acre. But, at this low rate, the spray is so fine that it can drift badly. On one occasion, spray drifted onto a neighbor's wheat field, and the Dixons' insurance company had to pay damages. The Dixons believed that Paraquat was "safer" to use than Roundup, but ICI Corporation did not recommend using Paraquat with less than 20 gallons of water per acre, and Roundup could be used at rates below this. This made the choice of herbicide and rate of application a matter of balancing risk and cost.

After 1992, new herbicides and Roundup Ready soybeans have largely solved the weed control problem in soybeans.

The Dixons' achievement in constructing a satisfactory no-tillage cropping system in Hickman County, Kentucky, has brought several awards, including "Best Conservation Farmer of the Year" in 1982 by the Kentucky Association of Conservation Districts.<sup>28</sup>

### *Continuing Dissonance: Unsolved Problems in Cropping System*

Growing full-season, no-till soybeans has been plagued by the inability to satisfactorily control "mares' tails" (giant ragweed), wild mustard, and pokeweeds. In 1980, for example, the Dixons used Paraquat to kill weeds at planting time, but the mares' tails came back, and part of the beans had to be disked up and replanted. Since then, they have used Roundup

two weeks before planting, trying to kill everything while the weeds are still small. But, killing these weeds and keeping the field clean have been difficult. The Dixons have not found an herbicide that could be used over the top of soybeans to kill mare's tail and pokeweeds, and they have had to continue trying different strategies to keep the field clean.<sup>29</sup> "That's what we're doing now that we're frustrated about," said Davis Dixon (Dixon and Dixon 1992). "It's the most difficult thing; it's more difficult than no-till wheat, and it's more difficult than [weed control in] corn."

In recent years, broadleaf signalgrass has become the major weed problem in their corn. "It's a no-till grass because it thrives in moist bottoms, and no-till saves moisture," says Kirk Dixon.<sup>30</sup> Their present strategy is to apply Dual at planting time, then Accent when the signalgrass starts to come up.<sup>31</sup> They believe this gives good control if the spring is dry, but if it is wet, which is usually the case, only 75 percent control is obtained.

Small rodents—pine voles and field mice—are an increasing problem with no-till, especially wheat. There is no effective control for the pine voles, which build burrows and feed on plant roots. They create a dilemma for no-till systems because winter cover crops—rye or legumes—which protect soil from erosion also provide a favorable habitat. Discing (or plowing) destroys habitat and reduces the rodent problem.

Davis Dixon's (Dixon and Dixon 1992) general assessment of their current no-tillage farming system is instructive. "We have tried to . . . no-till just as much as we could. We get frustrated with it. . . . It's much easier to farm conventionally. I have said that I think a man might live longer [using conventional tillage,] if erosion didn't bother him. It [conventional tillage] takes a lot less thinking. It takes a lot less planning," and it's easier to get seed planted at the proper depth. With no-tillage, "you are continually learning."

### *Constructing New Farming Systems*

Before starting to no-till, the primary farm enterprise was raising beef cattle and hogs. When Davis and Kirk began to expand grain growing in 1974, they disposed of the beef cattle in favor of expanding hog production, which complemented the grain enterprise. In 1985, they had 1,200 acres of row crops and sold 1,200 head of finished hogs.<sup>32</sup> However, in 1994, as Davis Dixon began to reduce his involvement in farming operations, the hogs were sold, and Kirk Dixon now raises only corn, soybeans, and wheat.

### Earl Welborn and the Construction of a Conservation Tillage System<sup>33</sup>

At age 18, Earl Welborn left the university and started working as a mechanic for a machinery dealer to help his family. Three years later, in the fall of 1938, he borrowed a plow and tractor from friends and “broke 40 acres” of ground for a corn crop on his grandmother’s 200-acre Todd County farm (Welborn 1992). Taking over operational responsibility for the farm the next year, Earl plowed the field with two mules and a mare to plant the next crop. In 1942, Earl bought his first tractor (“well-used,” steel-wheel, 10-20 McCormick-Deering) a plow, and a disk. Earl set up a cropping rotation, plowing sod for a corn crop, seeding wheat or barley in the cornfield, and then after harvesting the small grain the following year, seeding the field back to timothy for hay. Livestock—cattle and sheep—were the primary enterprises, and most of the farm was in hay and fescue.

In a few years, Earl expanded by buying a “badly eroded” 200-acre farm and additional machinery. The poor condition of this farm aroused his interest in conservation. He helped establish the Todd County Soil Conservation District in 1946 and became one of the SCS officer’s first clients. With the agent’s technical assistance, Earl constructed several miles of terraces and waterways to prevent further damage to the eroded hillsides.

In 1960, Earl purchased another farm. It was crabgrass infested and Earl gained his first experience with herbicides, band-spraying corn rows with Atrazine while cultivating the middles. But, he continued to raise crops conventionally although gradually expanding the use of chemical weed control. In 1968, Earl sold the eroded, 200-acre farm and purchased another one closer to the original family farm. With three or four hired men, Earl raised tobacco, some corn, wheat, soybeans, sheep, and cattle on 600 acres.

### *Dissonance and Initial Action-Learning with a New Tillage Frame*

With the costs of farm labor rising during the 1960s, Earl Welborn became increasingly interested in the time-and labor-saving aspects of the new no-plow techniques being tried by farmers, which he had learned about through the farm papers and extension service meetings.<sup>34</sup> In 1967, he went to an Extension Service field day at the Young, Lilly, and other nearby Christian County farms where corn and double-crop soybeans in wheat stubble were demonstrated. Earl was particularly interested in the double-crop soybeans and the possibility of growing three crops in two years on his farm. Although a few farmers in the area

had double-cropped beans and milo in wheat stubble using conventional tillage, Earl knew that the yields were erratic, due to preparation time and moisture loss. Returning home, he borrowed a no-till planter from a friend and planted a few acres of double-crop beans on his own farm, and the outcome was satisfactory.

The next year, Earl bought an A-C no-till planter to plant seventy-five to eighty acres of corn in red clover and timothy sod. He applied Atrazine, Paraquat, and surfactant to kill the timothy and red clover. In 1968, this was a new application, which attracted the attention of Cooperative Extension weed specialists. The trial was highly successful. "From that time until now," said Earl Welborn (1992), "there hasn't been any corn ground plowed on the farm." With the same labor force, Earl was able to crop a larger acreage.

### *The New Tillage System*

During the next few years, Earl Welborn constructed the following tillage cropping system:

1. On corn ground, Earl applies anhydrous ammonia with a modified chisel applicator and uses the chisel marks as a guide to apply enough phosphate and potash for the corn crop and the following small-grain and soybean crops. He uses a modified applicator with 24-inch coulters followed by knife applicators set 2 feet apart.

2. Using a tractor with tanks and an A-C planter with a fold-up sprayer attachment, he no-tills corn in 30-inch rows and applies AAtrex, Paraquat, and surfactant to kill broadleaf and grassy weeds and stop weed emergence. In a few weeks, Banvel is applied over top the corn with a Hahn Hi-Boy boom sprayer to control surviving weeds.

3. After corn harvest, corn stalks are chopped, and the field is disced twice before drilling wheat.

4. After harvesting the wheat, soybeans are no-tilled in stubble, and a tank mix of Lasso, Lorox, Paraquat, and surfactant is applied for weed and grass control. A few weeks later, Basagran is applied with the Hi-Boy sprayer.

5. If the winter weather kills the wheat, the field is chisel plowed in spring and disced twice to kill weeds, smooth the ground, and apply Treflan preemergent weed control. Soybeans are drilled, and a few weeks later Basagran applied with the Hi-Boy.

Herbicide tanks mounted on his tractor, a modified tool-bar planter to allow variable-width row spacing, and a fold-up boom sprayer were an early Welborn one-pass no-till planting innovation.<sup>35</sup> Location of the

spray boom behind the planter makes possible a more accurate application of chemicals than if the boom was mounted in front of the tractor where tractor wheels and disk openers would disturb placement of the chemicals. A fold-up feature enables Earl to get to the planter boxes when necessary. Earl's mechanical ingenuity also enabled him to construct a no-till nitrogen applicator that evenly applies anhydrous ammonia on sod or corn stalks with "No tracks, no trash, and no trouble" (Guebert 1983, 28-T).<sup>36</sup>

Unlike many other farmers who have tried no-till, Earl Welborn never had a problem with johnsongrass. This was primarily due, he felt, to two factors. The farm was fairly clean of johnsongrass when he started no-tilling, and he has pursued a strategy of complete eradication of any that appeared. He spot-treats any johnsongrass early, and at harvest time he cuts off the seed heads of any overlooked plants, treats the plants with Roundup, and waits two weeks to begin harvesting. However, viney weeds, such as morning glory, did become a problem, which is a reason for getting the Hi-Boy sprayer to apply Banvel and 2,4-D over the top when corn is 20 to 24 inches tall.

With the success of his conservation tillage and grain-growing systems, Earl Welborn began reducing his livestock operations. He quit feeding pigs in 1971, and in 1979 sold his cattle and leased out his pastures. Meanwhile, Earl expanded crop production. In 1979, for example, he raised 170 acres of corn, 170 acres of small grain, 170 acres of soybeans, ninety acres of fescue for seed, and seven acres of burley and dark tobacco. By double cropping, Earl Welborn utilizes up to 147 percent of his tillable acres. The tobacco acreage keeps him below 150 percent.<sup>37</sup>

### *Recent Action-Learning: Further Tillage System Adaptation*

Although with the tillage system, which he constructed in the 1970s, Earl Welborn was able to control most weeds, he has shifted to newer herbicides to control johnsongrass (Accent and Beacon) and to Bronco, a mixture of Lasso and Roundup, to get a better "burn down" of weeds and cover crop for no-till corn.

Earl started planting both corn and beans in 30-inch rows but was eventually persuaded that narrower rows of soybeans would provide better weed control and higher yields. To do this, he purchased three additional planting units to plant 18-inch rows; however, to get this spacing after corn planting in 30-inch rows, he had to shift nearly all the planting units on the tool bar, which took him and his hired man two days. This time-consuming process convinced Earl to buy two more planting



units and plant 15-inch-row soybeans. At this width, the soybeans canopy and begin to suppress weeds at four weeks.

With no-tillage saving time at spring planting time, the pressure time for field work shifted to the fall when it was necessary to harvest two crops—corn and soybeans—and plant one (i.e., wheat and/or cover crop). To ease this pressure, Earl shifted to a short-season soybean variety for about one-third of his crop. Then he could harvest corn, short-season beans, and longer-season beans, and could plant wheat. Also, he bought larger machinery—a larger corn head and a larger bean head—and purchased a 24-hole grain drill.

Earl readily acknowledges, however, that he has not yet perfected no-tillage cropping for all crops. He has not been able to develop a satisfactory system for no-tilling small grain. To sustain yields, he believes that residue from the previous crop must be incorporated. Earl uses a reduced tillage system. When “[y]ou get a 125, 150 bushels per acre corn crop,” Earl Welborn (1992) believes, “it takes some pretty heavy tillage to get that incorporated and plant a [small] grain crop.” His strategy is to use a “deep, offset type bog disk—big heavy disc—and try to cut the ground four to five inches deep, and then we follow with a smoothing disk. Sometimes we chisel the land and then use a smoothing disk on it to get an adequate seed bed.” Garlic and onions, which tillage helps control, are another deterrent to no-till, although he recognizes that Harmony (a newer herbicide) could be used to control them if the ground was not too wet to get on at the right time to spray.<sup>38</sup>

Despite this disappointment, the strong interest in soil conservation has been important in the more than two decades’ effort to develop conservation cropping. It spurred him at the beginning of his farming career to build waterways and terraces to protect the highly erodible land on the farm, which in any case was kept in pasture. As a result of the sustained interest in conservation, Earl Welborn’s conservation program was so well developed that when the 1985 Farm Bill came along, he was credited with having a completed Farm Conservation Plan already in place. A few years ago, he was recognized as a “Master Conservationist” by the Todd County Soil Conservation District.

The soils and weeds specialists of the Cooperative Extension Service have been key figures in Earl Welborn’s informational network. He has used their recommendations on soil testing, fertilizer, and herbicide use in the technical scripts of his conservation cropping system. The annual corn and soybean meetings and the annual farm machinery show have also been important sources of new ideas.



### John Barnett and the Reconstruction of Conservation Cropping in North Central Kentucky<sup>39</sup>

John Barnett started farming with his father on the 150-acre, Henry County farm in 1940. With horses, they raised about twenty-five acres of corn, a similar acreage of wheat, and some tobacco. The remaining acreage was in pasture for cattle. Most of the grain was fed to hogs. The father and son expanded operations in 1946, buying another 150 acres. In 1950, John began managing the tobacco and livestock part of the farming enterprise himself. Soil conservation programs aroused his interest in controlling erosion, and he began a 15-year effort to construct terraces and waterways on cropland where slopes varied from 4 to 12 percent. All other sloping fields were seeded in permanent pasture, and he took advantage of the soil bank program to set aside erosion-prone cropland, which he seeded in fescue and bluegrass. John also actively participated in the affairs of the Soil Conservation District, eventually serving a term on the board.<sup>40</sup>

#### *Initial Dissonant Event and Action-Learning*

From 1960 onward, however, beef cattle production became less and less profitable while family needs continued to grow. When the University of Kentucky Cooperative Extension Service established a farm business analysis group in the area with a farm management consultant in 1966, John was one of the first to join. As John Barnett (1992) remembers, "When I got into the Farm Analysis program, it showed that farm profitability depended a lot on the efficient use of the land. That is, every acre that could be used for producing grain crops was more profitable than one that was producing hay or pasture [and cattle]. So, I started looking for ways to increase the [crop] acreage and got word about the no-till corn production in Western Kentucky at Harry Young's farm. I went on a tour there [at a Field Day] in 1967."

The labor- and soil-saving aspects of the system as well as its economic advantages impressed John Barnett, and he decided to try it. He hedged his bet, however, by modifying his Case planter to plant no-till. (If the system did not work, he could at little cost return to the old system.) To plant no-till, he mounted fluted Allis-Chalmers coulters on a tool bar in front of the Case's double-disk openers so that the planter could penetrate untilled ground.

John Barnett planted his first no-till crop of corn in 1968. Although he had used herbicides to control weeds on a limited basis before, he had never used herbicides to completely replace tillage. He started with

the same formula Harry Young had used successfully and the Cooperative Extension Service recommended a combination of Atrazine and Paraquat, which was applied immediately after planting corn. The combination worked pretty well that first year.

*Further Dissonance and Action-Learning in Constructing a New Tillage and Cropping System*

Although corn yields were satisfactory, John quickly discovered that the “brushes and briars” as well as perennial weeds also thrived in untilled ground. He attacked the brushes and briars with brush killer, but soon decided that the western Kentucky rotation and a minimum tillage regime (rather than no-till) were the most effective weed and crop disease control strategy for him to use.

By 1972, John had worked out a tillage and cropping system, which he has followed with minor modifications ever since: (1) no-till corn in sod or cover crop, (2) after corn harvest, chisel plow, disc, and broadcast wheat along with phosphate and potash, which is disced in, and (3) no-till soybeans in wheat stubble. If the wheat winter kills, he no-tills corn into the failed wheat crop.

As the evidence mounted that erosion could be controlled with no-tillage, John expanded crop production onto the sloping fields, which he had long held in fescue and bluegrass. With the help of his two sons, he soon was planting 500 acres of corn and equal acreages of wheat and soybeans. He began using more nitrogen to increase corn yields, and the average yield rose from eighty bushels to around ninety bushels to the acre. With expanded crop production, he cut back livestock production and decided to lease out the tobacco.

As John continued to no-till and battle weeds, the weeds seemed to be winning. The herbicides he was using were losing their effectiveness. Then a routine soil test indicated that his soil was becoming acid, which interfered with the action of the preemergent herbicides. Lime corrected this problem, and this experience reinforced the importance of periodic soil testing.

*Recent Action-Learning: Adaptation of the New Conservation Cropping System*

While modifying his conservation cropping system, John Barnett continued to network with extension soil and crop specialists, manufacturers of herbicides, seed companies, and regularly attended field day demonstrations of new techniques. He was quick to try new herbicides, such as Roundup, Accent, Beacon, Fusilade, Poast, and mixtures (e.g., Bronco [Lasso and Roundup]), seeking to gain better control of perennial—johnsongrass, pokeweeds, bindweed—and some broadleaf weeds.

When his sons left the farm, John reduced cropping to about 300 acres of corn, an equal acreage of wheat, and 400 acres of soybeans on the 800 acres owned and rented. The 1,000 to 1,100 acres of crop is a land efficiency of around 130 percent. In the mid-1980s, when a set-aside program for corn acreage was established, John began growing full-season soybeans on the set-aside acreage, as well as on wheat acreage that winter killed.

The loss in soybean yield due to delayed planting when there was a late wheat harvest troubled John Barnett. He realized that he could sacrifice some of the wheat yield for the greater yield in the high-valued soybean crop if he could plant soybeans in the wheat before it ripened. But, the tractor and no-till planter wheels destroyed between 20 and 25 percent of the wheat crop. John solved this problem by fitting his tractor and planter with narrow, custom-built steel wheels and raising the planter frame 4 inches to clear most of the ripening wheat. This innovation enables him to plant soybeans earlier in the ripening wheat at the cost of only losing about 5 percent of the wheat crop.

At present, John Barnett raises crops by himself with a little part-time help and the use of contract operators. He contracts herbicide application for corn and soybeans as a way of getting quality application and the latest technology. John also hires a contractor to spread phosphate, potash, and wheat seed in the fall, which John then discs in, because fall harvesting and wheat planting has become the pressure time for fieldwork. Although recognizing that he could save fieldwork time by purchasing a larger six-row, 30-inch planter and a new corn head for the harvester, John believes that his age and short working-time horizon makes such an investment unwise.

### *Continuing Dissonance*

Like other conservation tillage farmers, John Barnett has not found a better solution than minimum tillage to satisfactory weed and disease control in wheat production. With his present no-till grain drill, which he uses to no-till soybeans in 7-inch rows, he could no-till wheat. Although this would save some time during the busy fall season as well as money (for contractors), his present opinion is that this advantage does not outweigh the cost of lower yields from no-till relative to his minimum till system.

### Tom Porter and the Construction of a No-Till Corn System<sup>41</sup>

In the 1930s when farms were failing, Tom Porter's father and grandfather purchased a farm in Hopkins County and rented it out on the usual

crop-share basis. The rolling upland soil was productive but highly erodible when plowed and cultivated for crops.<sup>42</sup> During the summers, young Tom liked to come from Nebo, where the family lived to work on the 440-acre farm. He saw huge gullies develop in some of the fields—one large enough to hide a tractor. In 1936, the new Soil Conservation Service enlisted the assistance of the Civilian Conservation Corps (CCC) in constructing terraces and waterways on this eroded field to demonstrate the new approach to soil conservation. Years later, Tom Porter would cite these events and a friendly neighbor's advice to save his soil as the defining experiences in his lifelong commitment to soil conservation.

In 1952, at the age of 26, Tom Porter and his wife moved onto and began operating the farm. Most of the 340 tillable acres were in fescue and pasture, and Tom began operating a dairy with twenty-five milk cows, cultivating only enough land for a little corn and 7.5 acres of dark tobacco. His crop rotation was corn followed by wheat and a forage crop. Difficulty in controlling viney weeds (e.g., morning glory) prompted Tom to begin spraying with 2,4-D after the initial cultivation. In 1960, he sold the milk cows and switched to raising beef cattle and hogs, expanding grain growing for cattle and hog feed.

#### *Initial Dissonant Event and Action-Learning*

In 1961, the wheat crop failed, and Tom Porter was persuaded by a neighbor and the county extension agent to go on a tour of a sheep farm at the Experiment Station in Dixon Springs, Illinois. The purpose was to learn about the possibility of raising sheep. While at the field day, however, he saw a plot with a good stand of corn that had been planted in killed grass sod by a planting machine with coulters. This interested him because he wanted to expand corn growing on the upland field, but had not done so because of the fear of erosion.<sup>43</sup> The Illinois cropland was similar to Tom Porter's—relatively thin, about 18 inches of topsoil above a fragipan—that holds rainwater in the top layer of soil and easily erodes. A fescue sod could hold the soil until the corn crop was up.

Tom was impressed too with the possible saving of machinery and fuel costs. The idea was consistent with his belief “that the least you can do to the ground and get a stand of corn and kill the weeds the better you are, both yield-wise and the ground itself” (Porter 1992).

But, with the type of planter that he had and the herbicides that he knew how to use, Tom did not think that he could no-till effectively. Instead, he decided to try wheel-track planting, which had been featured in *Hoard's Dairyman*. For the next 3 years, Tom planted corn in the river-bottom fields using the wheel-track method.<sup>44</sup> He plowed the ground and then planted with the machine offset to plant in the wheel

tracks. But, the plow-plant process was slow and left the ground rough and difficult to cultivate.

*Second Dissonant Event: Initial Action-Learning in Constructing Continuous No-Till Corn*

Tom Porter continued to visit the no-till trials at Dixon Springs, and he expanded his informational network. When the University of Kentucky started running trials and having workshops in Christian County in the mid-1960s, he began attending these.<sup>45</sup> Tom talked with Shirley Phillips (UK Extension Agronomist) and Charley Wyatt, a TVA soil specialist, about no-tillage cropping. On several occasions, Tom visited Harry Young's no-till plots and talked with Young and other farmers about no-tilling. Several cattlemen and dairymen in the local area also began to no-till, which provided a local network of interested farmers.

When Allis-Chalmers came out with its no-till planter in 1967, Tom Porter was ready to purchase one and try no-tilling. Tom planted part of a field before it became too wet, spreading Atrazine to kill the wheat cover crop. But, it "wasn't a real good burn down herbicide. . . . [The corn crop] wasn't a failure . . . but it wasn't much of a crop" (Porter 1992). Nevertheless, Tom was impressed with the conservation aspect and was determined to construct a practical no-tillage system.

The success of Tom Porter's neighbors in no-tilling corn in their sod pastures or hay fields prompted Tom to try no-tilling corn in timothy after cutting it for hay. But, Atrazine did not kill the timothy, which came back and stunted the corn. Tom learned that, after cutting timothy for hay, he must wait until the timothy started new growth to apply Paraquat to kill it. In 1972, Tom Porter joined the Ohio Valley Farm (Business) Analysis Group, and the analysis confirmed the profitability of corn production.

*Next Steps in Constructing a Continuous Corn System*

For the first three or four years, Tom Porter aerial seeded wheat after corn and disced it in. The next spring, he killed the wheat cover crop and no-tilled corn. Tom did not harvest the wheat because he had never gotten a good wheat yield on his farm, and he preferred corn to the less profitable full-season soybeans.

Tom soon discovered that it was easier to get a good stand, and thus a good yield, of no-till corn on the rolling uplands than on the bottom lands. He found that the bottoms usually were too cool and wet to no-till before the first of May.<sup>46</sup> By discing the bottom land twice and then putting down fertilizer and preemergence herbicide and discing again, the ground dried out and warmed fast enough for him to plant corn

before the first of May. Moreover, the emergence of no-tilled corn in bottoms, more than minimum-tilled corn, seemed to be adversely affected by heavy spring rains, which helped keep the soil cool, slow plant emergence, and reduce yields. On the cool and moist bottomlands, Tom thus found that the soil and moisture saving, and cooler soil temperatures, of no-till were not advantageous. Tillage also tended to disrupt and suppress the mouse population as well as easing weed control. For these reasons, Tom only rarely no-tilled the bottom fields.

In a few years, Tom found that vines, especially morning glories, trumpet vines, and wild sweet potatoes, were becoming a major problem especially in the moist bottoms. Atrazine and Princep applied at planting time did not provide satisfactory control, so he purchased a Hi-Boy spray rig to apply Paraquat and a "little 2,4-D" when the corn got shoulder high to control vines. "It burns off the lower leaves but doesn't seem to hurt the yield much so long as it [the chemical] doesn't get in the spurl" (Porter 1992).

#### *Continuing Dissonance with No-Tillage Cropping*

One year the wild millet or foxtail became a very bad problem in the corn, and to plant the next year, he burned the field and worked up the ground. But, he has not had this problem again.

With no-till, the mouse population began to build up. On the bottomlands, Tom quit seeding wheat in corn and reverted to minimum tillage, which disrupted the mouse dens. On the uplands, he began discing the fields two or three times every two or three years to reduce the mouse population.

#### *Recent Action-Learning: Adapting the Continuous Corn Cropping System*

Although Tom Porter did not have johnsongrass on his upland fields when he started no-tilling, it gradually became prevalent. To solve this problem, he began to rotate to soybeans every two or three years so that he could use different herbicides. When Accent and Beacon became available, he quickly began using them. But, he still rotates to soybeans occasionally to help manage weed and disease problems, and in 1992 he planted 100 acres of soybeans. For one of his fields, however, this is the forty-first year that it has been in corn.

Accent has also helped him solve the problem of shattercane in the bottoms for which he could not get good control with Sutan or Eradicane.

The mouse problem has been one of the most difficult to solve. This problem compelled Tom Porter to give up the idea of seeding a vetch cover crop in corn because rodent damage had earlier convinced him to

quit seeding wheat as a cover crop. For many years, Tom was able to suppress the mouse population by disking badly infested fields; this option was suddenly closed by passage of the Clean Water Act, which resulted in a ban on the cultivation (disking) of sloping fields. Since passage of the 1985 Farm Bill, Tom has followed a strategy of spraying the corn ground two weeks before planting, which encourages the mice to leave, and after two years of corn rotating to soybeans one year. If, in spite of this, the mouse population builds up, a light disking will be sufficient to suppress the population (Porter 1999).

The 1985 Farm Bill, which required the development of approved farm conservation plans for farmers receiving benefits of government programs, although complicating the control of field mice, had the positive impact of encouraging many other farmers in the area to switch from tillage to no-tillage of corn. It was a relatively easy development because most had been no-tilling soybeans in wheat stubble, had the equipment, and were familiar with the necessary technical routines.

### Worth and Dee Farms: The Ellis Brothers' No-Tillage Cropping and Livestock System<sup>47</sup>

In 1970, three brothers—Mike, James, and Robert Ellis—formed a partnership to operate the 2,100 acres in west central Kentucky, which they had inherited, and fifty leased acres. All three brothers had graduated from the University of Kentucky: Mike (agronomy), Robert (dairy science), and James (metallurgical engineering). Although James and Robert had principal responsibility for the hogs and beef cattle operations, respectively, the cropping program was Mike's primary responsibility. In 1974, Robert sold the beef cattle and started a 200-cow dairy, which he now operates with four employees. During the next two decades, the brothers acquired an additional 1,000 acres and in 1992 operated 3,150 acres, the 200-cow dairy, and the hog enterprise. In 1991 with two employees, James Ellis grew and sold 3,000 finished hogs.

In the 1960s, while the three brothers were in college, their father primarily had a beef cattle and tobacco farm. As an undergraduate in agronomy, Mike had attended one of the field days at Harry Young's farm. But, when he decided to plant his first corn crop in 1967, he plowed and planted the sixty-seven acres in the conventional manner. As he said, "I did everything wrong that year, but everything turned out right." Due to planting on an alfalfa sod and a favorable season, he got one of his highest corn yields ever.

The year was eventful in other respects: he and his father joined the Ohio Valley Farm Analysis group, and the group made a trip to the field



day at Harry Young's to see no-till corn and soybeans. Two other farmers near the Ellis', who had been thinking about no-tilling, also began experimenting with no-till corn in 1967. Service in the Air National Guard then interrupted Mike Ellis' farming for 2 years.

*Dissonance, Networking, and Construction of a Conservation Cropping System*

When Mike returned in 1970, the brothers formed the farm partnership and began deciding what to do. The Farm Analysis reports were decisive. With beef cattle, they were making \$20 an acre, and Harry Young in western Kentucky was making \$100 an acre with corn, soybeans, and wheat. The Ellis' had an abundance of sloping land that would rapidly erode producing crops, unless they were no-tilled. Mike decided to learn how to no-till, purchased a four-row Allis Chalmers no-till planter, and began networking.

By 1970, several local farmers were already experimenting successfully with no-tillage, and the State Soil Conservation Service agronomist (Dennis Colson) had become very knowledgeable about many of the technical aspects of no-tillage. Mike found his advice on spraying techniques invaluable.

That year, Mike decided to no-till 309 acres of corn. It produced well enough that he decided to no-till 372 acres in 1971, and over 500 acres the following year. Corn prices soared in 1973 and 1974, and in 1975 they rented another farm and expanded to 800 acres of no-till corn.

Meanwhile, they had been expanding the wheat and soybean acreage. With the new no-till planter, Mike had planted fifteen acres of full-season soybeans in 1971. That fall, he minimum tilled a small wheat acreage, and the next summer double-cropped fifty-nine acres of soybeans. He expanded to 122 acres of wheat and to double-crop, no-till beans in 1973. To plant wheat, Mike sowed seed with a spreader on the back of a truck and disced in the seed (as Harry Young had done). Mike grew wheat and double-crop, no-till soybeans until the price of wheat collapsed in 1976; then he started growing full-season no-till beans.

Although the wheat and soybeans were marketed, most of the corn, until the acreage was expanded in 1989, was fed to the hogs and the dairy cattle. Both of these operations produce a lot of manure, which is collected in lagoons. Periodically, these are emptied and the manure spread on fields. Using research information showing that leaf area of a growing crop was greater when plants were grown on tilled ground, the Ellis' chisel in the liquid manure before disking and planting silage corn or small grain. No additional fertilizer is needed on these fields.



Mike found that no-tillage suited the central Kentucky soils, which were relatively shallow, highly porous, silty loams, over limestone sediments. Crops required timely rains, and no-tillage saved soil moisture and increased organic matter in the soil. One particular rainfall event impressed him with the soil-saving aspect of no-tillage. A half-inch thunderstorm one spring day was followed by another storm in early evening that left a neighbor's plow furrows full of water and muddy water 3 inches deep flowing across the road, but Mike's adjacent no-till field had no water runoff; all was going into the ground.

### *Action-Learning with Equipment*

In 1972, the Ellis' added two planting units to the four-row A-C planter, making a six-row planter. Two years later, they purchased another six-row planter and mounted a hinged tongue between the two so that both units could be pulled with a single tractor. They further modified the new planter by adding depth-gage wheels so that a constant planting depth could be maintained, regardless of slope of the field. The tongue was hinged so it could be folded up, and the coupled planter transported endwise on a trailer on the road. But, it took about two hours to make the transition. In 1979, Mike attended a cropping workshop at Purdue University, which emphasized the importance of timely planting. That fall, Mike purchased a John Deere 7000 Maximerge planter, which can be made ready to transport in only 3 minutes.

In 1970, the Ellis' purchased a 400-gallon Hahn sprayer. But, the hinged booms flopped badly on uneven ground, making careful placement of chemicals impossible. Thereupon, they purchased a 60-foot, hydraulic-controlled boom, with shock absorbers. This helped control the boom and enabled the boom to float, instead of bounce, over bumps.

### *Additional Dissonance Events, Networking, and Adaptive Tillage and Cropping System Construction*

From 1976 when the wheat market collapsed until 1979, Mike Ellis did not grow wheat and grew only full-season no-till soybeans and corn. However, broadleaf weeds in soybeans, especially giant ragweed, became an increasing problem because no satisfactory over-the-top herbicide was available.<sup>48</sup> With recovery of wheat prices, Mike began slowly to increase the wheat acreage again, in part to aid weed control, and to double-crop soybeans. By 1983, he had 510 acres of wheat and soybeans.

The experience with the no-till soybeans convinced Mike Ellis that he should be no-tilling wheat. In 1983, he rented a haybuster drill, which

Harry Young liked, to plant 687 acres of no-till wheat and repeated the process in 1984. In 1985, Mike purchased a no-till drill for wheat and soybeans. In the process, the careful records, which he kept for farm analysis, indicated that he saved \$18 an acre in labor and machinery costs by no-tilling the wheat.

The new haybuster drill enabled Mike to take the final steps in no-tilling soybeans. Originally, he had planted soybeans with his A-C planter in 30-inch rows. When research showed higher yields and better weed control with 15-inch rows, Mike started running the planter over the field twice, the second time between the initial 30-inch rows, to get 15-inch row widths. The new drill plants in 7-inch rows. To increase his soybean yields and reduce weed pressure, Mike also increased the seeding rate from 100 to 120 pounds per acre, an idea he picked up from attending the Purdue Cropping Program workshop.

While attending a Purdue Cropping Program, Mike also learned to use a linear program to analyze the farm's resources and determine the most profitable mix of enterprises. The analyses aided his decision to abandon wheat when prices were low, and later to return to wheat when prices improved. The economic benefit of rotating crops to reduce weed control costs was also demonstrated by the analyses.

The analyses heightened Mike's awareness of the current cost-price squeeze and the disadvantage of heavy reliance on corn in an area where the average yields are 20 percent lower than in the main corn belt. For this reason, the Ellis' rely heavily on hogs and dairy cattle to get added value from the corn they grow.

The effort to reduce input costs is driving trials of new herbicides. For years, Mike Ellis had used Atrazine and Princep on his corn. Now, he is experimenting with various alternatives and rotations in the effort to reduce costs.

Cost is an important factor in getting the right amount of nitrogen at the right time on no-till corn. When Mike began no-tilling, he was told that no-tillage required up to 20 percent more nitrogen because some would be tied up in the surface mulch. To reduce nitrogen leaching, he followed a recommendation to delay the application of one-half the nitrogen. Next, Mike and Jim Ellis noticed that the protein levels of their corn (and wheat) were low despite use of 150 units of nitrogen. Also, some of the corn would start yellowing. While attending a no-till field day at the University of Tennessee at Milan, Mike learned that nitrogen injected below the mulch would boost yields. Except for nitrogen in the starter fertilizer, Mike began to delay all nitrogen application and to inject it between 2 and 4 inches below the mulch. This solved the problem of low protein level and leaf yellowing.

Then Mike Ellis began noticing that the corn, or wheat, in fields where manure had been spread the previous year was unusually green. This led Mike to think that he had applied too much nitrogen, and he began cutting the nitrogen application on such fields by one-half. Now, based on information from research at Penn State, Iowa State, and Purdue, Mike is testing the nitrate level when the corn is a foot tall, and applying only as much nitrogen as is needed. He expects that the next step will be to monitor nitrate levels as nitrogen is applied and to apply only as much as each point in the field needs.<sup>49</sup>

From Mike Ellis' point of view, the lack of a satisfactory cover crop is one of the biggest unsolved problems in no-till cropping. He is convinced that he could reduce the costs for both herbicide and nitrogen if he had the right kind of mulch. In the first place, the heavier the mulch, the less need for herbicide. Moreover, if a cover crop was available that grew heavily in the fall, taking up nitrogen and/or fixing it and returning it to the soil when knocked down in the spring, less nitrogen would be lost and have to be applied.

### Conservation Tillage in Iowa

Corn belt farmers have different topographic and climatic conditions than farmers in Kentucky and other southern states. Researchers found that no-tillage was less-suited to the flat landscapes of the central corn belt from Iowa to Ohio than the rolling landscapes with loamy surface textures found along the Ohio River and in Kentucky (Blevins 1984). Corn seedling emergence and early growth responds to rising spring soil and air temperatures, increasing as temperatures rise from 50° to 86° Fahrenheit and declining at higher temperatures (Phillips 1984). Corn planted at the latitude of Des Moines, Iowa, or Moline, Illinois, has only five-sixths as many days of favorable growing temperatures between May 3 and June 14 as that planted at the latitude of Louisville, Kentucky. Because surface mulch suppresses temperatures at the soil surface, any tillage system leaving mulch on the surface tends to result in lower yields. Corn belt crop advisors and farmers were not slow in recognizing this constraint.

Nevertheless, the benefits of reduced tillage were palpable, and from 1954 onward, farmers in the central corn belt—Iowa, Illinois, Indiana, and Ohio—were periodically appraised of alternative tillage methods through farm papers and institutional sources (i.e., primarily state extension services).<sup>50</sup> In 1957, *Wallaces Farmer*<sup>51</sup> featured four "Short Cuts for Corn Tillage"—listing, ridge tillage, mulch tillage, and minimum tillage (wheel-track planting). The story identified the soil conditions for which each method was best suited as well as the benefits of each method in

saving time and cost, reducing soil packing, improving water infiltration, and reducing erosion and weed growth. Mulch tillage, recommended for medium to light soils, aimed to leave crop residue on the surface by reducing tillage. Wheel-track planting, which had been developed in Michigan and Ohio (Buchele 1967; van Es and Notier 1988), was suggested as a minimum tillage method. Contour listing of row crops, in which seeds were planted in the furrow between ridges thrown up by the double-shovel planter, had been practiced as an erosion control method in drier areas since the 1930s. Ridge planting was a mirror image of listing, in which seeds were planted on the ridges, rather than in the furrows, and was recommended because in cooler climates the soil warmed fastest on the ridges. The latter method had been developed by USDA and Missouri soil scientists during the 1940s, and Iowa State University scientists began studies of the method in the mid-1950s (Nelson 1997).

Of the new methods, mulch tillage offered the greatest benefits in soil and labor saving but was rejected by most Iowa farmers because the surface mulch kept the soils cool, delaying planting and reducing yields. Ridge tillage was the most challenging of the methods because of the difficulties in forming, and planting on, the ridges. Ernest Behn is one of the first farmers to construct a successful ridge-tillage system.

### Ernest Behn and the Construction of Ridge Tillage in Central Iowa<sup>52</sup>

Ernest Behn grew up during the 1930s on an Iowa farm, graduated from Iowa State University, and started to work for the extension service. The U.S. Air Force called him for three years of service; then Behn gained an appointment as a Work Unit Conservationist with the Soil Conservation Service.

While with SCS in 1958, he purchased a 120-acre farm in Boone County, which had about thirty acres of loamy (Clarion) sloping land, seventy acres of "dark and level Nicolette with some potholes of heavy Webster clay," (Behn 1982, 12) and twenty acres of pasture. Prior use of conventional tillage on the hill land had left it so badly eroded that spots of yellow subsoil were beginning to appear. Despite his reservations, Behn did not have an alternative to conventional tillage in raising corn and soybeans.

#### *Initial Dissonance and Adaptation*

The first year's experience in raising a crop with conventional tillage methods, however, demonstrated both the fallacy of plowing and disking in order to help infiltration of air and water and the wisdom of SCS recommendations on water management. As Behn (1982, 17) puts it: "after

each little rain the [soil-laden] water would come running off my small hillsides and head for the river. Out on the so-called level field, water ran to all the . . . potholes, drowned the crop, then went into a tile and down the river.”

Behn was equally aggravated with the work involved in conventional tillage itself. The pressure of field work, beginning with corn harvest in the fall and ending when the corn was laid by the following summer, was intense.<sup>53</sup> Altogether in the process, Behn typically made fourteen trips over each field. Other Iowa farmers were turning to minimum tillage to save trips over the field. Surely, Behn thought, there was a better way to raise crops and save soil and time. He had spent a lot of time as a conservationist trying to convince other farmers that contouring and terracing would pay, and he determined to do it on his farm.

The next year, Behn built terraces and grassed waterways on the thirty-acre hillside, and he set up a good rotation. This did indeed keep the soil on the hillsides, but in 2 years the terraces were level with collected silt, and Behn faced the prospect of rebuilding them. Meanwhile, the potholes on the flat areas continued to fill with water and drown the crop. There was not any way to terrace around the potholes.

One problem was how to keep the soil in place between the terraces. It occurred to Behn that the soil protection provided by crop residues that were left on the surface, an idea with which Behn had been familiar since starting as a soil conservationist, might keep the soil in place between the terraces. Moreover, if somehow every row of crop were planted on a contoured ridge, the ridge itself would be a miniterrace. He could build such ridges with his cultivator and without government assistance.

The available information about planting into crop residue, however, was not encouraging. Behn had read and heard about all the problems. Crop residues, while saving soil, kept it cool and wet, which delayed planting and in Iowa resulted in poor seedling emergence; corn stalks clogged cultivators, interfered with weed control and resulted in higher insect populations. The result was higher costs and lower yields. Despite these difficulties, Behn knew that other farmers were trying different reduced tillage methods, which left the soil surface covered for part of the fallow period at least, and that saved time and soil. Behn decided to experiment.

### *Initial Action-Learning: First Steps in Constructing a New Tillage System*

In 1962, Behn purchased a 7-foot chisel plow with which he could loosen the soil 8 to 10 inches deep but leave most of the crop residue on

the surface. After harvesting the 30-acre sloping field that fall, Behn first chopped the stalks with a horizontal rotary chopper. He then broadcast fertilizer and followed this with a tandem disk to further cut up the stalks so that the chisel plow would not become clogged. Then Behn chisel-plowed twice, first at a 45-degree angle to the terraces and then parallel to the terraces. The little ridges and valleys helped hold winter snows and, along with the remaining crop residue, held the soil and aided infiltration of spring rains even after the field was disced and leveled just before planting. Chiseling and discing reduced the stalk residue and allowed the ground to warm for timely planting.

In the spring of 1963, Ernest Behn planted corn at the rate of 21,500 kernels per acre and got a stand of 20,000 plants per acre. He spread granular herbicide and insecticide in the row and ten days after the first rain he used a rotary hoe to kill germinating weeds. In the fall, he harvested 126 bushels of shelled corn per acre, 20 percent more than in any previous year. More surprising to Behn (1982, 20), "the terraces never carried any water!" This meant that all the chemicals—fertilizer, herbicides, and insecticides—remained on the field instead of going down the river. Behn decided to repeat the process the next year.

To manage insects and diseases, Behn rotated corn and soybeans. But, he had one reservation with his new tillage system: The problem was not with the system's soil-saving and crop performance but with its fit with his livestock operation. By chopping the corn stalks to chisel-plow, Behn destroyed a source of winter feed for his cow herd. Thus, he decided to modify the system by first letting the cows forage the corn field before starting the tillage process.

### *Dissonance Again and Further Action-Learning*

The delay, however, proved costly. Behn was only able to finish one-half of the chisel plowing before winter weather halted field operations. The remaining land had to be chiseled and the entire field disced in the spring. At planting time, the weather had turned dry, which resulted in a poor "stand on the spring-chiseled area, and a 20-bushel reduction in yield later" (Behn 1982, 20). Although deeper planting might have improved the stand, the dry ground also rendered the surface-applied herbicide less effective.

This experience impressed Ernest Behn with the riskiness of delaying fall tillage operations as well as of the deep chisel plowing in the spring. He recognized that he faced a trade-off between winter feed for one beef cow for each four acres of corn fodder, and corn yield the following year unless favorable weather prevailed. Through experimental tri-

als over the next several years, Behn became convinced that only shallow chisel or sweep plowing following discing should be attempted in the spring. He also learned that incorporating the preemergent herbicide in the soil increased its effectiveness.

Although generally pleased with the chisel-plow tillage system, Behn was disturbed by the number of trips he was making over the field, which ended with the field having relatively little surface-residue protection. But, unless the residue was eventually removed, it would keep the ground cool, delay planting, and result in poor yields. Again, circumstances intervened.

### *Decisive Informational Event*

In 1965, Ernest Behn went to Arizona to visit relatives and by chance discovered that the cotton farmers were using bedders to build ridges on which they planted cotton while running irrigation water between the ridges. Where there was cotton on ridges, Behn saw corn. He seized the idea of planting corn on ridges in Iowa.<sup>54</sup> "But, instead of leaving the valleys clean between the rows . . . [the] corn stalk residue or bean straw [could be put there]. This would hold moisture, prevent erosion, and allow the tops of ridges to warm up and dry out," thought Behn (1982, 26). Moreover, "freezing and thawing and weathering of this ridge during the winter would produce a nice, mellow but firm seed bed" for corn or beans in the spring (Behn 1985, 43).

### *Networking and Construction of Ridge-Tillage System*

Returning home, Behn sought out researchers at Iowa State and Nebraska universities and found to his surprise that researchers at both places already were studying such a system.<sup>55</sup> That summer at the Iowa State Fair, he saw a Buffalo Till Planter and decided to buy one.<sup>56</sup>

Behn set up an experiment for his 1966 crop. Through the field to be till-planted, he "plowed three strips, each 20 rows wide" (Behn 1982, 64). On these, Behn chopped stalks, disced, fall plowed, disced again, harrowed, and cultivated before planting. Nothing was done until spring on the remainder. Before planting the test areas, however, Behn chopped the stalks, then he till-planted with the Buffalo Planter in the rows of the previous year's crop. By pushing the residue off the row, the soil became 8° to 10° warmer than in the row middles.

Both areas received the same fertilizer applications before planting and during planting, and herbicide was applied in rows. The entire field was cultivated twice. On the second cultivation of the till-planted area, however, Behn adjusted the disk hillers to throw as much dirt as possible



back into the row in order to build contoured ridges for next year's crops. The yield on the till-planted strips was sixteen bushels per acre larger than on the conventionally tilled strips, and Behn figured that he saved \$10 per acre in seedbed preparation costs. The experiment was repeated three more years, and the average four-year test yield of corn on the till-planted ridges was eight bushels more per acre than in the conventional strips. Ernest Behn had a system to save surface residue and soil in a northern climate, which lowered costs and gave better yields. Residue between the ridges so slowed water movement and aided infiltration that water seldom ran to even the low spots. On the level field, which formerly flooded in every rain, the potholes no longer filled with water and became as productive as the other areas.

### *Further Action-Learning: Refining the System*

When planting on contoured ridges, the planter tended to slide to the inside of the ridge. Where this occurred, subsequent cultivation to kill weeds often took out part of a row of corn. To prevent this from happening, Behn first mounted stabilizers from the cultivator on the planter to help it stay centered on the row. But, eventually he purchased a Beet Harvester Row Finder, which he adapted to fit on the planter's accessory bar. The swinging tractor drawbar was fitted with a hydraulic cylinder connected to the row finder. When the row finder moved right, it signaled the hydraulic cylinder to move the drawbar accordingly, thereby keeping the planter centered on the row regardless of the curve in the row.

Ridge-till planting required changes in the use of herbicides. After a few years of experience in planting corn after beans, Behn settled on "8 pounds of Lasso II in the row at planting time . . . [followed] by 3 quarts of Bladex right after planting" (Behn 1982, 63) to control annual grasses and broadleaf weeds. If any weeds were starting to grow, he sometimes added 2,4-D to the Bladex. In planting corn after corn, Behn settled on a Lasso-Aatrex mix.

Soybeans after corn required a different combination: Lasso in the row followed by 5 quarts of Amiben right after planting. If weeds were beginning to appear at planting, 2,4-D in the Amiben helped get the broadleaves. If weeds were well up, Modown and a surfactant burns everything down, and then either Amiben or Lasso in the row at planting time keeps the rows clean. Behn always cultivates once or twice to clear the midrow weeds and repair the ridges for the following year. The system is flexible enough so that it can be modified, depending on changes in weed and weather conditions.



## Conservation Tillage and Cropping in Kentucky and Iowa: A Summary

During the 1960s, innovative farmers in Kentucky, Iowa, and other states who wanted to expand grain growing and to save soil began constructing radically different tillage frames and cropping systems. The new tillage frames had different tillage and cropping objectives, were based on new knowledge of soils and plants, and employed new and different techniques. With the new tillage systems, the resource and crop production outcomes were markedly superior to those obtained with their conventional systems, and the new systems thereby became a new system of agriculture, although they did not immediately, or entirely, replace conventional tillage systems.

### *Context*

Before the critical events triggering innovative activity, the innovators, with the exception of the Dixons, had been interested in soil conservation, sufficiently so that they had undertaken various soil-conserving measures. However, they felt compelled by the economics of farming to expand cropping. All had gained some experience with chemical weed control, although only Harry Young had begun to use herbicides as a substitute for cultivation.

### *Dissonant Events*

At some point, each innovator experienced a dissonance-producing event that elicited transforming action. For Harry Young, not one but several events, including his own failures and successes in using herbicides, and the discovery of McKibben's experiment, were decisive. For several, it was the discovery that they were making very little, if not losing, money and that corn and soybeans could be grown more profitably and successfully with no-tillage. Others, observing storm-caused destructive erosion determined that no-tillage was the only feasible alternative. The distinctive element in every case was that the salient event provoked a conviction to begin constructing a new and better tillage system, and, once embarked on this course, the innovative farmer never wavered despite periodic failures.

### *Networking and Repetitive Action-Learning*

The decision to make a paradigm shift in tillage practice invariably provoked expanded networking to gain information. Usually this included professional farm advisors as well as other successful innovative farmers.

These innovators invariably started no-tilling one crop—corn or soybeans—and worked to construct a satisfactory tillage system for that crop before constructing no-tillage systems for additional crops. Only two of the innovators, however, have developed satisfactory no-tillage for nearly all crops, except tobacco. Others minimum till wheat, for example, or no-till crops on certain soils but not others. In every case, two to three decades after the initial decision to construct new tillage and cropping systems, the innovators are still adapting their systems due to changing economic or biophysical conditions or new technical innovations. In this sense, the conservation cropping systems are unfinished and continually evolving.

### *Constraints*

The farmer and his farm are the key constraints of the new conservation tillage systems—no-tillage, ridge tillage, minimum tillage, etc. Each farmer had to construct a system for his farm that he could manage (i.e., make work to his satisfaction in resource conservation and development, crop productivity, and profitability). The monitoring of biophysical and economic conditions and the management of technical operations continue to challenge the abilities of these farmers. All of the innovators are aware of the greater complexity and managerial difficulty involved in no-tillage crop production. Controlling weeds, insects, rodents, and diseases continually elicits new cycles of adaptive learning in the management or technical scripts of their tillage and cropping systems. As Davis Dixon (Dixon and Dixon 1992) puts it, “No-tilling helped us. . . . But, it takes a lot of planning . . . a lot of thinking. . . . I wake up in the middle of the night thinking about it, worrying about it, trying to figure out a solution. . . . [Conventional plowing, disking, planting,] that’s easy, anybody can do it. This [no-till] way takes a lot more thinking, a lot more nerve.”

Differences in farm biophysical environments—soils, climate, flora, and fauna—are the other most important source of conservation cropping system variability. To construct their new tillage and cropping systems, the innovative farmers had to become more knowledgeable about soil types, structure, temperature, and moisture levels as well as the nutrient and acidity levels of their soils. The normal range of variation of each factor determines the particular form of the tillage system. For example, Ernest Behn constructed a ridge-tillage system to cope with Iowa’s cooler climate. Tom Porter gave up trying to no-till the cool and wet bottomlands in Hopkins County, Kentucky.

Factor variation within a normal range compelled these farmers to make coping adjustments in their tillage systems. To manage this varia-

tion, innovative farmers expanded soil-monitoring practices. Soil testing became more common. With conservation tillage, soils have improved in organic matter, structure, and fertility, enabling the farmers to reduce inputs. The farmers gained new knowledge of soils as well as of weeds and weed ecology.

### *New Technology*

Successful construction of new conservation tillage systems depended on the development of several new machines and new herbicides. Of the conventional tillage equipment, only the tandem disk and chisel plow retain limited roles in the new conservation tillage systems. Plows, harrows, conventional planters, and the like were abandoned and replaced by various types of chemical applicators and no-till planters. Initially, the innovative farmers substantially modified, or constructed, the sprayers and planters that enabled them to attain the new tillage and planting objectives. The modification of machinery "to make it work better" has continued to be important even with the newest machines.

### *New Goals*

The new system objectives included a differently constructed farm landscape. With conventional tillage, farmers often had to choose between saving soil by keeping it covered with low-value grass and forage crops, or costly terraces and substantial soil loss in growing more profitable grain crops. With the new systems, these two objectives—soil conservation and optimum economic returns—converged, and a trade-off was avoided. Instead of a grassy landscape, parts of which were occasionally in erodible clean fallow or growing crops, a landscape was constructed that was continuously covered with crop residue, cover crops, or productive crops. For Davis Dixon and Tom Porter, no-tillage made possible the growing of grain crops on upland soils without fear of substantial soil erosion. John Barnett put the change in the landscape, which no-tillage made possible, most succinctly when he said: "[Formerly,] our land had been fenced so that the steeper slopes were in permanent pasture. As we got into no-tilling grain crops, we saw that you didn't have anything like the erosion on those steeper slopes [as with conventional tillage]. We took out a lot of the fences and pretty much raised grain crops on all the land" (Barnett 1992). Ernest Behn's vision of his farm landscape covered with contoured ridges, which saved soil while providing a warm, moist plant bed for growing corn and beans, provided the impetus for constructing a ridge-till plant system. In these respects, the new tillage systems have made the cropping of much farmland sustainable.

The innovative farmers constructed cropping systems on a larger and more profitable scale than ever before. Labor savings made possible the planting of larger acreage with the same manpower. In Christian County, for example, farmers who started no-tillage cropping expanded the acreage farmed by 40 to 50 percent within the first 5 years (Choi 1981). Moreover, with no-tillage cropping, cropland can be cropped more efficiently (i.e., more of the land could be kept in high-valued economic crops the year around). As Earl Welborn (1992) puts it: "Last year . . . I had 136 percent land use of tillable acres. We have . . . [on occasion] been as high as 147 percent land use, and the reason we can't quite get to the 150 percent mark is because of [our] tobacco acreage." Conservation tillage systems have made possible the construction of cropping systems that are both more productive and more profitable.

### *Sociocultural Identity*

These innovators have developed a new identity. The image of the independent plowman, powerfully turning the sod, creating civilization and community has faded, the subject now only of legend. These conservation tillers have constructed identities around the image of a manager of natural resources. The soil, water, economic and noneconomic plants, and animal and insect life are parts of an organic environment for which they have management responsibilities. They are in step with the Wisconsin farmers, who see the soil as a living organism whose health they are responsible for sustaining (Romig et al. 1995; McCallister and Nowak 1999). The healthier the soil, the more productive it is, and productive activity is the farmer's national mandate. As John Barnett (1992) put it: "I've invested a lot of time and effort into developing something here . . . [that will] be here for the next generations."

But, the farmer's identity as natural resource manager has a broader focus than merely managing soil and productive as well as nonproductive plants. Especially since the 1990 Clean Water Act, these farmers have increasingly accepted responsibility for aspects of the wider environment (e.g., the quality of water and endangered plant and animal species). Because the agroecology with which the farmer is concerned is a complex set of systems, so is its management for the benefit of future, as well as present, generations.

### Notes

1. Researchers had identified several differences in the top soil layer that with stubble mulches were potential sources of reductions in wheat yields: lower nitrate content, greater intensity of microbial activity, toxic plant growth

inhibitors, and susceptibility of wheat in warmer soil to root rot (McCalla et al. 1962).

Certain weeds (e.g., cheatgrass and downy brome) were also greater problems in stubble-mulch tillage and continuous wheat. Yield and grain quality losses resulting from cheatgrass limited the expansion of no-till wheat in the northern Great Plains and Pacific Northwest, and in the southern Great Plains, growers reverted to conventional tillage as effective herbicide control was not developed. See *No-Till Farmer* (August 1997).

2. In Kentucky, burley tobacco in the central part of the state and dark tobacco in the western areas were the most profitable farm commodities.

3. Especially for farmers with land already in conservation reserve, rotating cropland into grass or legumes, which was the principal strategy of minimizing soil erosion, meant a substantial loss of revenue.

4. The parity ratio (ratio of prices received to prices paid as a percentage of the 1910–14 average), including government payments, in 1960 was 81 and falling (Tweeten 1979, table 6.3), and income from farming was only 53.9 percent of nonfarm income (Tweeten 1979, table 6.5).

5. Except for raising tobacco, cotton, wheat, and specialty crops, the dominant farming system strategy in the upper South and much of the Midwest during the 1950s was to make money from dairying or raising livestock—beef cattle or hogs. Grain crops were grown primarily as feed grain for one's livestock, secondarily to sell if livestock prices fell. In Kentucky, tobacco and beef cattle (and fescue pastures) remained the dominant farming system for three decades after World War II.

For the impact of enterprise dominance on adoption of farm practices, see Coughenour (1972).

6. This account is compiled from articles in *The Progressive Farmer*, Vol. 76, October 1961, p. 36; Vol. 76, November 1961, p. 17; Vol. 77, April 1962, p. 45; Vol. 78, March 1963, p. 29; Vol. 78, April 1963, p. 41; Vol. 80, March 1965, p. 40; Vol. 81, March 1966, pp. 62, 74D; Vol. 83, January 1968, p. 21; and Vol. 84, February 1969, p. 24; Also, Phillips and Young (1973), Young (1972); Davie (1996), and John Young (1999).

7. Farm papers regularly featured stories of "successful farmers" who used lime, manure, and fertilizer, and legume crops to build soil, and terraces, strip and contour cropping to conserve it, according to SCS recommendations. For example, see "Land Blankets" in *The Progressive Farmer* (Vol. 63, No. 8, August 1948, p. 15); "Master Farmer . . ." in *The Progressive Farmer* (Vol. 63, No. 9, September 1948, p. 15); "Three L's are Paying Off" (lime, legumes, and livestock) in *The Progressive Farmer* (Vol. 67, No. 8, August 1952).

8. See "Stop Weeds in Corn and Beans" in *Wallaces Farmer* (Vol. 83, May 1958, p. 16); and, "Control Weeds with Herbicides" in *Wallaces Farmer* (Vol. 84, April 1959, p. 30).

9. See chapter 5.

10. The trial attracted regional attention. See "What? Grow Corn and Not Plow?" by Pete Head in *The Progressive Farmer* (Vol. 76, March 1963, p. 29); "No Plow Corn" by Bob McGaughey in *Kentucky Farmer* (Vol. 98, October 1962,

pp. 14–15). Shirley Phillips, Extension Crops Specialist, was an especially interested observer of this initial no-till trial.

11. In Tennessee and Kentucky, there was a narrow planting window between wheat harvest in June and July 1, which was the last date for planting short-season soybeans. With conventional tillage, extension specialists estimated the chances of a good crop of soybeans as one year out of five. But, as early as 1960, some farmers in Tennessee had begun using a “mulch planter” to double-crop soybeans in wheat fields. Soybeans would be planted after disking the wheat stubble once or twice. This saved both time and moisture. By 1966, the practice had spread to Ohio and Mississippi River counties—Fulton and Union—in western Kentucky (Barksdale 1966).

12. Machinery companies, including International Harvester and Allis-Chalmers, had developed “mulch planters” or “tillage planters” (e.g., see “What’s Available in Mulch Planters” in *The Progressive Farmer*, Vol. 76, April 1961, p. 136), but all required some tillage either prior to planting or in advance of the planting unit. The new Allis-Chalmers planter had a fluted coulter to cut through surface residue and slanted disks to open a slot for the planting shear, which made a trench into which seed and fertilizer were placed. A press wheel following the shear pressed soil into the trench over the seed.

13. See chapters 8 and 9.

14. See “Their Land Produces 150%” by Earl Mannering in *The Progressive Farmer* (Vol. 91, January 1976, pp. 19, 31).

15. In 1968, Harry M. Young, Jr., estimated that the costs of producing corn alone were cut by \$3.50 per acre using no-tillage methods (*The Progressive Farmer*, Vol. 83, January 1968, p. 21). When this is applied to twice as many acres (as could be cropped using conventional methods) and coupled with the additional profits from second-crop soybeans on wheat land, the economic attractiveness of the new tillage-cropping system is easily seen.

16. An article on “Corn Diseases Can Be Costly” by S. H. Phillips in *The Progressive Farmer* (Vol. 84, April 1969, p. 30) indicates the complexity of the farmer’s strategy for dealing with this problem. Phillips suggested (1) using disease-resistant varieties, (2) rotating crops, (3) using necessary amounts of major and minor minerals, (4) controlling insect vectors, and (5) using seed treatments.

17. See *The Progressive Farmer*, Vol. 76, November 1961, p. 17.

18. See *The Progressive Farmer*, Vol. 78, March 1963, p. 29; Vol. 80, March 1965, p. 40; Vol. 81, March 1966, p. 62; April 1966, p. 72; Vol. 83, January 1968, p. 40; and Vol. 84, February 1969, p. 24.

19. The order of such a large quantity of Paraquat prompted a trip by the chemical company field agent to the Young farm to see the large orchard (Young 1999; Davie 1999).

20. See “Herbicides for Zero Tillage of Corn in Killed Bluegrass Sod” in *Results of Research in 1966* by the Agricultural Experiment Station of the University of Kentucky, 79th Annual Report (p. 20). Also reported in “Zero Tillage of Corn and Weed Control Materials Work Well in UK Tests” in *Kentucky Farmer* (Vol. 103, March 1967, p. 38).

21. See "Cultivators Stay in the Barn," in *The Progressive Farmer* (Vol. 76, November 1961, p. 17); "Johnson Grass Can Be Controlled in Crops," *The Progressive Farmer* (Vol. 82, April 1967, p. 39); "New Problems from Old Weeds," *The Progressive Farmer* (Vol. 84, February 1969, p. 58); "It May Pay You to Plow Little or None," *The Progressive Farmer* (Vol. 86, January 1971).

22. See *The Progressive Farmer* Vol., 77, April 1962, p. 45; and Vol. 78, April 1963, p. 41.

23. "Harry Young sprays 50 gallons of water per acre, at 50psi, and travels at four miles per hour. On the sprayer he has 8003 nozzle tips and carries the boom about 17 to 18 inches off the ground, in stubble ground" ("Notes on No-Till," in *Kentucky Farmer*, Vol. 105, January 1969, p. 15). This provides even coverage, keeps booms steady, and the 50 psi drives spray through mulch. " 'Straw mulch is our biggest enemy to good weed control' says Young." Chopping or mowing of straw allows better herbicide penetration.

24. Farmers were periodically cautioned through the pages of farm papers to use proper care in using dangerous chemical herbicides and insecticides. Some farmers used contractors to apply the chemicals, rather than do so themselves; others developed greater skill and care over time. See "How Farmers Handle Chemicals" in *Wallaces Farmer* (Vol. 90, March 20, 1965); "How to Clean Equipment Used for Farm Chemicals" (Vol. 90, June 1965, p. 20); "Chemicals Can Be Dangerous" (Vol. 93, February 10, 1968, p. 62). *The Progressive Farmer* provided similar advice to southern farmers: "How to Clean Boom Spray" (Vol. 76, May 1961, p. 99); "Play It Safe with Chemicals" (Vol. 79, May 1964, p. 44); "Would You Poison Your Well?" and "Safe Way to Handle Chemicals" (Vol. 82, May 1967, pp. 28 and 59, respectively).

25. See Harry Young, Jr., "A Chemical's Performance Depends on What, When, How," *The Progressive Farmer* (Vol. 81, April 1966, p. 72).

26. In 1969, the partnership that Harry Young, Jr., had with his brother Lawrence and father (Harry Young, Sr.), was dissolved, and Harry Young, Jr., took over operation of the total farm (Young 1999).

27. Based on Dixon and Dixon (1992, 1999).

28. *Hickman County Gazette*, August 1, 1985. In 1979, the Dixons also received the Governor's Award for Outstanding Non-point Pollution Control, and in 1985 they received a commendation "for outstanding achievement in the conservation of the Nation's soil and water resources" by The National Endowment for Soil and Water Conservation.

29. Basagran, Blazer or Status, Cobra, Galaxy, Pursuit, Reflex or Flexstar, and Storm are now recommended "good" postemergence control of mare's tail (Cooperative Extension Service 1997). In 1997, however, there was no recommended chemical control of pokeweeds in farm crops.

30. Broadleaf signalgrass is an annual grass, which is common in southern United States, and is expanding into Kentucky as tillage declines and the grass more readily reseeds.

31. This strategy is consistent with recommendations in Cooperative Extension Service, (1997).



32. *Hickman County Gazette*, August 1, 1985.

33. Based on Wellborn (1992, 1999); Tom Curl, "No Tillage Whacks Fuel Bill" *The Progressive Farmer* (Vol. 95, May 1980, p. 76); Bill Buchanan, "Row Width Can Vary with These Rigs" *The Progressive Farmer* (Vol. 97, February 1982); Bill Buchanan, "Nitrogen Application Made Easy" in *The Progressive Farmer* (Vol. 97, March 1982, p. 72D); Alan Guebert, "A True No-Till Applicator" in *Successful Farming* Planting Issue, March 1983); "Lessons Learned from No-Till Experience" in *The Progressive Farmer* (Vol. 104, October 1989, p. 46).

34. For example, see "Another Look at No Plow-Corn" in *The Progressive Farmer* (Vol. 81, March 1966, p. 740), and "One-Trip Tillage-Planting Cuts Costs" in *The Progressive Farmer* (Vol. 81, May 1966, p. 34). By 1966, the Cooperative Extension Service had established a team of specialists—soil, crop, weed, and agricultural engineer—to establish field trials and inform farmers about no-tillage crop production.

35. Bill Buchanan, "Row Width Can Vary With These Rigs" in *The Progressive Farmer* (Vol. 97 No. 2 Soybeans, pp. 6–7).

36. See also Bill Buchanan, "Nitrogen Application Made Easy" in *The Progressive Farmer* (Vol. 97, No. 3, p. 72D).

37. Earl Welborn was an early member of the Pennyroyal Farm Analysis Group, and decisions to reduce livestock production and expand crop production were guided by the results of these annual business analyses. For the period—1970 to 1976—net returns to management for most Pennyroyal grain farms were higher than those of cattle and hog farms in four of the seven years. See *Kentucky Farm Analysis Groups* (Annual Summary). In 1989, Earl Welborn reported that compared to the farm analysis group as a whole, his gross returns were \$34 above average, his expenses were \$14 per acre below average, and his net returns were \$48 per acre above the group average ("Lessons Learned from No-Till Experience," *The Progressive Farmer*, Vol. 102, October 1989, p. 46).

38. In 1994, John Dale (son-in-law) assumed operational responsibility for the farm and has used Harmony to control wild garlic and onions satisfactorily. Earl believes that John Dale has better timing in using herbicides (Welborn 1999).

39. Based on Barnett (1992); "Wheels of Fortune" *Farm Futures* (May–June 1991, p. 3).

40. Although John Barnett drastically changed his farming system from primarily forage and livestock to grain growing, tilling much of the sloping land and eliminating the hard-won terraces in the process, his interest in soil conservation has never faltered, and he was recently named a "Master Conservationist" by the Soil Conservation District.

41. Based on Porter (1992, 1999).

42. The granada soils have a fragipan from 18 to 24 inches below the surface, which slows water infiltration, increasing the saturation of the top layer during periods of rainfall, and thus increasing runoff and erosion of unprotected soil.

43. Tom Porter was among a group from Hopkins County who also saw George McKibben's 1961 no-till experiment.



As Tom Porter recalls, when he had mentioned to his neighbor that he wanted to plow and cultivate the field along the road, which had been terraced in 1936, the old man “kind of shook his head. He said, ‘Now, Tommy, don’t let that wash away again.’”

44. The belpap soils in the flat bottomland are much less erodible than the granada rolling, upland soils.

45. See chapter 5.

46. The poorly drained soils in Hopkins County, which remained cool and wet longer in the spring, presented farmers with a more difficult problem in no-tilling than that encountered by the Youngs and other farmers in southern Christian County, where the soils drained better and warmed more quickly. Iowa researchers had discovered by the mid-1950s that a mulch tended to retard the warming up of soils by three to five days in the spring. (Later studies indicated that seedling emergence was retarded both by cool and wet conditions [Phillips 1984; Blevins 1984]). Farmers in Kentucky, Iowa and elsewhere soon discovered the practical manifestations of this problem. See “What Soil Types for No-Till Crops” by Shirley Phillips in *The Progressive Farmer* (Vol. 84, February 1969, p. 24), and “New Tillage Systems . . . Help Cut Costs and Save Moisture,” by Monte Sesker in *Wallaces Farmer* (Vol. 94, February 22, 1969, pp. 18–19).

47. Based on Ellis (1992).

48. The use of herbicide-tolerant soybean varieties, (e.g. Monsanto’s Roundup Ready) helps no-till farmers deal with this type of problem.

49. Mike Ellis is keeping up with Lloyd Murdock’s (West Kentucky Research Station) evaluation of the Soil Doctor. It is a nitrate analyzer connected to the front of the nitrogen applicator that continually feeds information on the soil nitrate level to a computer controlling the rate of nitrogen application. It applies as much nitrogen as is needed to bring each spot in the field to a preset level.

50. See “Till Planter Gains Favor” in *The Prairie Farmer* (Vol. 126, April 17, 1954, p. 20); “Plant Corn with Less Work” in *Wallaces Farmer* (Vol. 79, November 20, 1954, p. 12).

51. Vol. 82, April 20, 1957, p. 24.

52. Adapted from Behn (1982, 1984, 1985) and “Minimum Tillage Cuts Costs” by Wilbur Hovic in *Wallaces Farmer* (Vol. 92, April 22, 1976 pp. 38–9).

53. The routine included chopping stalks and plowing as much ground as possible before the ground froze. Then in the spring, the remaining ground was plowed and immediately disced and harrowed to break up clods and level and firm the ground. Fall-plowed ground also had to be disced and harrowed to kill weeds. Rain, of course, would lead to erosion, and then a crust would form. High winds would create a dust storm. After a rain, it was often necessary to disc and harrow again. Finally, fertilizer would be spread and the crop planted. Weed control then required three or four hoeings or cultivations.

54. Although Ernest Behn had not considered ridge tillage prior to 1965, the idea of ridge tillage, as a method to cut tillage costs, and help poorly drained, cool soils dry out and warm more quickly, had been introduced to Iowa farmers

as early as 1957. See, "Short Cuts for Corn Tillage," in *Wallaces Farmer* (Vol. 82, April 20, 1957, p. 24).

55. Till planting had been developed in Nebraska in the mid-1950s, and an effective till planter was developed by agricultural engineers at Kansas State University. In 1961, Fleischer Mfg. Company started producing till planters (Buchele 1967). In 1965, subscribers of *Wallaces Farmer* were alerted to till planting, along with wheel-track and listing, as minimum tillage methods that reduced trips over the field, reduced soil compaction, and saved moisture ("Too Much Tillage Can Cut Yields," Vol. 90, April 3, 1965, p. 76). Ridge-till planting, which combined the advantages of till planting and ridge tillage, however, was a relatively novel idea, which few Iowa farmers were aware of until Behn's experience was reported. See "Minimum Tillage Cuts Costs," by Wilbur Hovic in *Wallaces Farmer* (Vol. 92, April 22, 1976, pp. 38-39).

56. It had a sweep to cut off the top of the ridge and push residue aside followed in line by a boot to plant seed, two small disks to cover the slot, and a press wheel to press soil around the seed.

# 7

## The Construction of New Tillage Systems in Australia

*Farming systems in Australia have evolved over two centuries, largely by trial and error. European methods were adopted initially, followed by American ideas. These, together with Australian-farmer innovations and natural and man-made disasters, have resulted in ley-farming which is currently practiced over the cropping zone . . . and in stubble retention farming in the summer-rainfall areas.*

—Pratley and Rowell (1987, 2)

The social construction of conservation tillage systems in Australia followed a different path than in the United States. Although soil conservation authorities and farmers in Australia began to engineer water management systems almost as quickly as in the United States, farmers on the Darling Downs in Queensland were slower to make changes in their tillage systems. One reason was the lack of farming experience. A substantial part of the Darling Downs was rarely cropped until the 1950s and 1960s, and the accumulated experience of the consequences of bare fallow of these lands was limited.<sup>1</sup> Important too was the relatively low level, compared to the United States, of research and extension effort in soil conservation. Research to dispel misinformation about surface residue and to gain understanding of conservation tillage on the Downs developed slowly.<sup>2</sup>

Finally, although the eastern Darling Downs borders the large winter cereal crop-growing area, the summer and winter crop area of the Downs is relatively small, only 842,720 hectares (2,106,800 acres). The soils vary from brown clayey loams, crackling clays, and self-mulching clays, to hard setting loams (Douglas 1987). Farming properties range from relatively small fifty hectares to more than 600 hectares with a median of 260 hectares (650 acres) (Chamala et al. 1983). The relatively small number of farmers and the diverse farming conditions limited the interests of large machinery and chemical companies in developing appropriate

technologies. The diverse conditions also handicapped the indigenous development of appropriate conservation tillage technologies.

Although farmers on the Darling Downs did not take the opportunity provided under the Soil Conservation Act of 1965 to establish trusts for the purpose of building conservation works, individual farmers were sufficiently alarmed by erosion of their fields to begin building contour banks and waterways. Such action was encouraged by amendments to the 1965 Act, raising the amount of the subsidy and broadening the scope of activities for which it could be used (i.e., stubble mulching, minimum tillage machinery, and dozer blades) (Pauli 1978).

The construction of soil conservation works on the Darling Downs increased dramatically after 1973 as a result of the declaration of eleven shires as Areas of Erosion Hazard. Under the declaration, coordinated planning of water management could be undertaken by landholders, local authorities, and the Queensland Soil Conservation Authority (SCA). With a requirement to carry out water control works, many landholders took advantage of the subsidy provided to build contour banks, waterways, and drainage systems. By 1975, about 30 percent of the land, which the SCA had assessed as requiring contour banks and waterways, had been protected through the voluntary cooperation of landholders and SCA (Skinner et al. 1977). During the next 2 years, the treated area expanded by nearly one-sixth, and the area on which "contour measures, such as strip-cropping, were implemented . . . [grew by] almost one-seventh" (Pauli 1978, 112).

The planning and construction of conservation works on the Downs continued to expand during the following five years. A sample survey of grain growers on the Darling Downs in 1982 found that 81 percent had built contour banks and waterways on areas needing such treatment (Chamala et al. 1983). Even so, 31 percent indicated that additional works were needed.

The Queensland Soil Conservation Branch (SCB) authorities recognized in the early 1960s that erosion could not be completely controlled only with contour banks and waterways. To provide suitable space for farming with large equipment, contour banks on slopes had to be more widely spaced than necessary for adequate erosion prevention by mechanical means alone. Agronomic measures thus were required on contour-banked fields as well as on fields that did not require contour banks. These measures included strip cropping and retention of a stubble mulch.

In relatively flat areas subject to flood erosion, SCB officers initially worked to persuade farmers to intersperse strips of grain and grass or hay crops.<sup>3</sup> The next step was to persuade them to leave wheat residue

on the surface as a mulch. The first step in this effort was to convince farmers that the practice of burning stubble was harmful,<sup>4</sup> and that they should acquire equipment (e.g., chisel plows) that could handle stubble. Unfortunately, farmers were more easily persuaded that burning stubble was harmful than that machinery should be purchased to make stubble mulching a practical alternative (fig. 7.1 and 7.2).

The major problem for farmers was the lack of both stubble-handling machinery for weed control and planting as well as experience with such machines. Equally critical, the Department of Primary Industries (DPI) field officers had little experience or field data with various stubble-handling machines. In 1969, DPI took steps to correct this deficiency by arranging for the testing of stubble mulching equipment available in the United States and Canada. See chapter 5.

Farmers' evaluation of better stubble-handling equipment initiated progressive change in tillage practices. By 1982, except for winter to summer double cropping, farmers on the Downs very rarely burned stubble, and more than two-thirds either had a chisel or a blade plow (Chamala et al. 1983). Unfortunately, only a minority of farmers in 1982 primarily used these implements to retain a stubble mulch. Most farmers used the equipment as cultivators and continued to turn the soil using either a disc plow or offset discs in the first fallow cultivation. This



Figure 7.1. Double-disk tillage in Queensland. (Courtesy of Robert Bateman)



Figure 7.2. Sundercutter tillage in Queensland. (Courtesy of Robert Bateman)

was also necessary, they felt, to reduce the stubble and facilitate additional cultivation. Only 14 percent thought “zero-tillage” would increase profitability of farming, and only 3 percent had reportedly tried it.

Six years later—in 1988—however, a growing minority of grain growers had constructed (or were constructing) stubble-mulch tillage systems, and in 6 more years, in 1994, several growers had constructed no-tillage systems for their summer crops. The processes by which grain growers on the Darling Downs constructed conservation cropping systems, which they could manage, are described in the following case studies.

### Neville Ronnfeldt and the Social Construction of Conservation Cropping<sup>5</sup>

In 1954, when Neville Ronnfeldt was 15 years old, his father purchased Wyoming, the 735-acre home place. Mr. Ronnfeldt worked on this property with his father until 1964, when Neville began operating a 500-acre farm on his own. Four years later, his father turned over the operation of the home place to Neville. In 1988, Mr. Ronnfeldt and his two sons in partnership operated 3,800 acres—2,800 acres cropland and 1,000 acres hill and river valley pasture.

The property is located in an area with clayey sedimentary soils. The annual rainfall averages 26 inches, but the range varies widely. Flooding is only a problem on Wyoming when the summer storms are especially heavy.

The farming system has always been based on crops and livestock, although the balance of livestock and crops has shifted over the years in response to commodity prices. In 1988, Ronnfeldt and Sons had 200 head of cattle and 300 head of Drysdale—carpet wool—sheep. At that time, the principal summer crop was grain sorghum. In normal rainfall years, the cropping sequence started with a summer double crop of mung beans in wheat or barley stubble. After winter fallow, sorghum was grown 2 or 3 years in succession and followed by double-crop chickpeas back into winter wheat or barley. In 1988, Mr. Ronnfeldt normally foraged cattle on the sorghum stubble and sheep on the wheat stubble.

Between 1988 and 1995, for the following reasons, Mr. Ronnfeldt substantially changed this farming and cropping system.

### *Early Experience*

Although during the 1950s and 1960s, Mr. Ronnfeldt's tillage system was conventional—burn wheat stubble, plow with a disc plow, and cultivate the fallow to control weeds—he was receptive to information suggesting a new approach to soil and weed management. The initial step was made in the mid-1950s and involved the use of 2,4-D weed killer. Mr. Ronnfeldt's father purchased a 60-foot boom sprayer, which he mounted on the back of a truck, to spray pastures for cockle burr and winter wheat and oats for wild turnip. The Ronnfeldts did not attempt to spray fallow cropland to control weeds because they were pasturing fallow with sheep who helped control weeds, and because the idea of retaining mulch had not yet been widely promoted. Later on, they began incorporating Avadex<sup>6</sup> pre-plant to control "black (wild) oats" in winter crop.

### *Dissonance and Initial Action-Learning*

In 1965, a year after Mr. Ronnfeldt started farming on his own, a startling event occurred. He had burned the wheat stubble and started to plow. The ground was working nicely, but he stopped midway to do other chores. Two days later when he tried to complete the job, the ground, which had been moist when the stubble was burned, had dried so hard that the plow would not go into the ground. This prompted him to think: "There is something wrong here."

The next year, Mr. Ronnfeldt had a paddock (field) of millet that had been "worked once . . . but most of the stubble was still there, and there was plenty of moisture and the soil was fine." It worked easily with

offset discs, and Mr. Ronnfeldt thought: "if we could just get ground like this all the time, [we'd be right.]" This heightened his interest in moisture conservation and convinced Mr. Ronnfeldt to stop burning stubble.<sup>7</sup>

The importance of stubble in moisture conservation was reinforced again in 1968 and 1969, which were dry years. The cereal crops were light, and the first cultivation completely destroyed the little remaining stubble. But, in the summer of 1968–69, sheep had foraged two fields of wheat stubble until late February. Only 4 inches of rain had fallen up to that point, and Neville used a moisture probe to determine the amount of the remaining moisture. To his surprise, he discovered that the fields foraged by cattle had retained twice as much moisture as those that had been cultivated once. This impelled him to think about what had happened to the moisture in the cultivated fields.

In the dry conditions of 1969, every cultivation of the fallow to kill weeds resulted in dust storms. This made Neville Ronnfeldt think that it would be nice to be able to get rid of the weeds without cultivating, but using herbicides to do so did not seem to be cost-effective. Instead, he began to think about using a blade plow, which DPI officers were talking about, to leave the surface undisturbed.<sup>8</sup> But, it did not seem practical.

Neville began noticing that there was some erosion on his fields, and floods, although only an occasional problem, tended to move soil to the fencerows. The SCB and extension had been recommending strip cropping as a way to control erosion, and this seemed to Neville Ronnfeldt to be a practical solution. In 1970, with SCB's assistance, Mr. Ronnfeldt began developing contour strips for crops. The grass strips arrested the soil movement from the cultivated areas but left small ridges at the edge of each strip. Even so, Neville gradually expanded the practice of strip cropping, and by 1976, he had strip crops on all the land in the flood plain.

### *First Action-Learning Trials in Stubble Mulching*

While making these changes, Mr. Ronnfeldt was also considering changes in his tillage system. He knew that the DPI had sponsored the testing and evaluation of several pieces of equipment, including a blade plow. In 1972, Neville Ronnfeldt attended the field day at which Lindzey Ward demonstrated the operation of several stubble mulching implements. Neville was quite impressed with the blade plow, and said to himself: "That's the thing . . . we need, a blade plow to shear off all the weeds and leave the stubble on the ground." Pursuing this conviction, he discovered that Napier Brothers in Dalby had made a demonstration blade plow with 3-foot sweeps (instead of 6-foot sweeps on the John Deere model) and a three-point hitch. He located the demonstrator and



took it to one of his fields, which was so hard that he “couldn’t get a disc into it, but the blades went straight in and did a beautiful job and left all the trash on the top” (Ronnfeldt 1988a). So, he bought the demonstrator from Napier Brothers.

With the acquisition of the blade plow that would conserve stubble, there was need for other types of equipment that would work satisfactorily with stubble, especially a planter (drill) that would be able to place seed at the proper depth despite stubble on the surface. Because of Mr. Ronnfeldt’s interest in stubble mulching, Lindzey Ward (DPI) appointed him to the Plains Machinery Evaluation Committee (MEC).<sup>9</sup>

After the farmers had used the equipment, the MEC met to discuss how the machines had worked in their soil and stubble conditions. Representatives of local manufacturers—Janke, Gyal, and Napier Bros.—met with the committee and brought attachments to existing equipment for testing and evaluation. Within 6 months (i.e., in 1973), Gyal came out with the Gyal TX, a six-bar planter. It would plant a crop in heavier stubble than any other planter, and Mr. Ronnfeldt purchased one.

#### *Next Step in Action-Learning: Reduced Tillage.*

The constant pressure to reduce costs, as well as to save stubble, impelled farmers on the Downs, as in the United States, to consider using herbicides to reduce tillage costs. Herbicide costs, however, were too high and the novelty too great for farmers to try it. Nevertheless, sensing a market opportunity, Monsanto in 1978 and 1979 contacted Lindzey Ward for assistance in sponsoring trials of Roundup in controlling weeds in summer fallow.<sup>10</sup> Neville Ronnfeldt, along with several other members of the old MEC agreed to provide trial sites (Ward 1988; Scott 1988). The DPI planted and harvested crops on the trial sites. The trials involved conventional cultivation, partial herbicide substitution, and zero-tillage. For herbicide substitution, weeds were controlled by Monsanto field agents using Roundup and a boom sprayer. This effectively controlled the weeds and saved labor time.<sup>11</sup> Roundup was still patented, however, and it was so expensive that cultivation was less costly although more time consuming.

With the pressure to save time and with costs mounting, Mr. Ronnfeldt decided in 1981 to try, with Monsanto’s advice, his own experiment in controlling weeds in fallow with herbicides. The trial was successful. After some experimentation, he concluded that the most effective combination of herbicides was Roundup immediately after harvest and 2,4-D midway in the fallow period.

Neville Ronnfeldt quickly discovered that the new tillage system—stubble management and weed control with no more than one or two

cultivations with a blade plow—not only saved soil, time, and moisture but also increased the flexibility of field operations. The next year, for example, he was able to plant wheat and barley on hard setting red soil, on which cattle had foraged, after only 31 mm of rain. Several months later, he was able to plant sorghum on the same type of ground. Moreover, because mulch-till ground is firm, not boggy, Neville was able to plant very soon after a rain. Because the ground held moisture longer, there was more time to complete planting.

When Mr. Ronnfeldt started the new tillage system in 1981, he was cultivating 950 acres with a Ford 8700 and a Ford 5000. Since then, he and his sons have purchased larger equipment and expanded their farming operations to more than three times the acreage. In particular, they purchased a larger tractor and larger field cultivator equipped with an airseeder. (They no longer use either the blade plow or scarifier.) They have not hired additional labor, but instead use contract harvesters or sprayers as need be to sustain timely operations.

With the objectives of saving soil, moisture, and reducing costs, Mr. Ronnfeldt more often began to try double cropping with only one cultivation to apply fertilizer before planting rather than leaving the land fallow for 6 to 12 months. His tillage-cropping system thus became a new minimum-zero-tillage system. With this system, he started a new six-year cropping rotation: double-crop mung beans after wheat or barley harvest; winter fallow, summer crop sorghum for two or three years; double-crop chickpeas and back into wheat or barley for two years. The switch from summer to winter crops and vice versa by means of double cropping, rather than a long fallow, was possible because of the moisture saved through stubble mulching and reduced tillage and because of the time saved in planting with the cultivator-airseeder.

During the mid-1980s, Mr. Ronnfeldt planted various legumes—chickpeas, mung beans, cowpeas—for profit and to add nitrogen to the soil. He also occasionally raised corn and cotton in place of the basic summer sorghum crop.

After harvesting sorghum, Neville foraged cattle on the sorghum stubble, which also helped reduce the stubble and control the weeds. Similarly, the wheat stubble provided forage for sheep. In continuing this practice after development of his minimum-zero-tillage system, Mr. Ronnfeldt went against recommendations of the SCB, who argued that putting cattle and sheep on stubble would pack the ground and destroy too much stubble. However, Mr. Ronnfeldt argued that the cattle and sheep did not pack the ground unduly; indeed, the sheep hooves tended to harrow the ground, providing a mulching effect that trapped the moisture below. Natural weathering processes quickly restored soil

structure of over which cattle had ranged briefly. Meanwhile, the natural pasture would have good growth. Since then, the DPI has shifted course and is recommending ways to fit livestock into a conservation cropping system.

During the fifteen years between 1967 when Mr. Ronnfeldt stopped burning stubble and 1982 when his reduced-tillage system was finally constructed, the solution to one problem had revealed another as salient: weed control, soil or water resource development, or crop propagation. In the end, the traditional plow-cultivate tillage system had been replaced by a new, more efficient, and sustainable tillage system. When asked what had sustained his commitment over this period, Mr. Ronnfeldt (1988a) replied:

I was looking for a better way. . . . You should [always] be looking at the new ways as they come out to see if there is something better. Costs are going up all the time, you've got to keep trying to increase efficiency. . . . It's a challenge. . . . [One factor] is to go to bed each night with a sense of achievement. . . . If we see something wrong, we want to correct it. . . . [The aim is] to keep soil producing over a long period. . . . We wanted to [increase the farm size] and have a viable farm to pass on to the next generation.

### *Subsequent Environmental and Market Changes and System Adaptations*

When Mr. Ronnfeldt began minimum-zero-tillage in the 1980s, some in the DPI were concerned that the soil would become compacted if it was not plowed or ripped. But, Mr. Ronnfeldt argued that with zero-till, the country did not need it. With DPI supervision, Mr. Ronnfeldt prepared four test strips in wheat stubble: zero-till, blade plow, para-plow, and conventional cultivation. Monsanto measured soil moisture before and after the trial in each strip. "The zero-till was the wettest and softest of the whole lot and ones with the para-plow and the blade plow only had one percent more [moisture] than conventional cultivation" (Ronnfeldt 1988b).

With the assistance of a farm management consultant, Mr. Ronnfeldt recorded machinery costs, which were compared to that of seven other area farms. Over a three-year period—1985 to 1987—machinery costs in \$/hectare of cultivation averaged 48 percent of costs of the other farms in the area, and the average value of machinery on the Ronnfeldt farm in \$/hectare was only 50 percent of the comparison group. The data provided convincing evidence of cost savings. By 1988, Mr. Ronnfeldt had found solutions to most problems associated with his minimum to zero-tillage system.

Changes in family, environmental, and market conditions since 1988, however, have induced Mr. Ronnfeldt to change his tillage and cropping systems. Dryland cotton became a much more profitable summer crop than sorghum and has become Ronnfeldt's crop of first choice when sufficient moisture is available. A succession of relatively dry years in the 1990s, however, often made sorghum, which tolerates drought better than cotton, a necessary substitute.

The relatively dry years have compelled Mr. Ronnfeldt to abandon the 6-year crop rotation with double cropping to shift from winter to summer crops, which he had established during the 1980s when rainfall levels were more nearly normal. The mung beans and chickpeas were dropped when double cropping was abandoned. Instead, he tries to long fallow out of wheat or barley into a summer crop of cotton, and winter fallow to a sorghum crop and double-crop back into barley. But, dry years have made even this rotation problematic, and an "opportunity cropping" strategy (i.e., plant a crop, whatever is likely to be most profitable), whenever there is sufficient moisture to get the crop up, has become the common practice. He tried raising peanuts, but found that he was too far from a processing center for the crop to be profitable.

Falling wool prices eventually made wool growing unprofitable, and Neville sold his sheep. Cattle remained profitable, however, and when his youngest son joined the family farming enterprise 3 years ago, Mr. Ronnfeldt decided to begin feed-lotting steers with grain raised on the farm. With the increase in cattle, management has become more complicated because they are continually moving fences to new forage areas.

Due in part to the drier climate during the 1990s, Mr. Ronnfeldt has gone increasingly to strict zero-tillage to conserve moisture. Cultivation is confined to the wheel tracks when necessary to close cracks and level the ground so that the sprayer will be able to operate more effectively. Roundup and 2,4-D are still the herbicides of choice. To control bindweed in cotton, he has developed a shielded intrarow spray rig out of old chemical drums. The rotation from summer to winter crops works well in controlling resistant weeds.

As their zero-tillage system has stabilized, the Ronnfeldts have found that it can be operated successfully with only three pieces of machinery: a rotary harrow, boom sprayer, and no-till planter. Several years ago, they replaced the cultivator-airseeder with a double-disk opener Kinze planter.

During the 1990s, resource sustainability and local farmer-group planning for Landcare—soil, water, and environmental resources—have become the principal foci (Chamala and Keith 1995). Neville Ronnfeldt was elected chairman of the local Landcare group. The group identifies

major local, environmental problems and coordinates group resources in addressing the priority problems. Sustainability of the family farm has become the controlling idea in their vision of the future.

### Wayne Newton and Reconstruction of Conservation Cropping<sup>12</sup>

When Wayne Newton finished high school in the late 1960s, he started farming with his father in the Dalby area of the Darling Downs. The farm was located on brigalow, scrub, and black soils that were low in phosphate. In common with most other farmers, however, they had not learned the importance of soil testing and of building soil fertility, and their attempts to make a living raising winter wheat were poorly rewarded. After several poor harvests, Wayne left home and began working with his grandfather on a property that had better soils. The better crop yields impressed him with the importance of soil fertility.

In a few years, Wayne and his grandfather began trying to further improve soil fertility with fertilizer and were rewarded by even better yields. But, Wayne began to recognize that the soils had other deficiencies. The soils were low in organic matter. They crusted quickly after rains, and the water ran off instead of seeping into the soil.

During the 1970s, winter cereal crops—wheat and barley—were their principal cash crops. Broadleaf weeds, which flourished in these crops, cut yields and contaminated grain. To deal with this problem, they adopted a practice that was already fairly common in the area—spraying the fields with 2,4-D. Another problem that further increased Wayne Newton's awareness of the need to change farming practices was the difficulty of controlling various weeds (e.g., pigweed) in summer crops with cultivation. Somewhat later, he began to use Atrazine as a preemergent control of grasses and weeds in summer row crops. Although these experiences convinced Mr. Newton that chemical weed control was effective and practical, he did not then consider using herbicides to control weeds in fallow.

Wayne's concern with improving soils and controlling weeds became increasingly salient during the late 1970s, and he began to feel, as he puts it, that "there had to be a better way" (Newton 1988a.) Meanwhile, other farmers in the area were changing their tillage practices. In 1979, Wayne went to a field day on Hector Tod's farm nearby where Monsanto trials in fallow weed control and no-tillage crop production were discussed.

In 1981, heavy summer rains filled the broad flood plain, which includes parts of the black clay fields on his farm, and caused considerable erosion of top soil. This loss heightened Mr. Newton's interest in soil conservation and convinced him to begin strip cropping at right

angles to the flow of floodwater. He now crops the flat, black plains in alternate 100-meter strips.

By 1981, grain sorghum had become Wayne's main cash crop. After harvest, the typical procedure was to slash the sorghum stubble and cultivate to control sorghum regrowth.<sup>13</sup> Normally, three or four cultivations would be made to control weeds before fertilizing and planting a sorghum crop the next summer. After the third sorghum crop, the paddock would lay in long fallow (14 to 16 months) and be cultivated four or five times to control weeds before planting winter wheat or barley. After two winter crops, a long fallow would allow the storage of sufficient moisture to return to summer crop sorghum.

### *Key Dissonant Events and Action-Learning of a New Tillage System*

By 1980, Wayne Newton had become dissatisfied with the spray rig that he had been using to control weeds in winter wheat crops. It was mounted on a tractor and was outmoded. He needed better equipment for more effective use of Atrazine for in-crop summer weed control. During 1981–82, Mr. Newton read the available literature on spray rigs, looked at the ones available, and purchased a trailing spray rig that would provide greater flexibility in using herbicide sprays.

Coincidentally, the decision to purchase a new spray rig was made during the particularly wet summer of 1981–82. Not only did the flood damage some of the fields, but wet fields could not be cultivated to control sorghum regrowth (Newton 1988a; Scott 1988). Wayne Newton decided that to reduce erosion and control regrowth on 400 acres of sorghum stubble, he would try spraying. Not only was he able to kill the regrowth, but the following summer's sorghum crop was outstanding. Wayne attributed the higher yields to the greater soil moisture, which had been maintained by spraying instead of cultivating the sorghum stubble. During the fall of 1983, Wayne used herbicides to control regrowth on his entire sorghum crop and started experimenting with herbicides to control weeds in summer fallow (between winter cereal crops). Following Neville Ronnfeldt's advice, Wayne Newton cultivated once and applied anhydrous ammonia just before planting his summer crop with a Napier airseeder.

Wayne Newton's decisions to substitute herbicide for cultivation in fallow weed control and to minimum till before planting, he recognized, were made in the context of two important related developments in the area. First, since starting to raise sorghum as his most important summer cash crop, controlling regrowth had been a major problem. Second, Monsanto Corporation, the DPI, and several other farmers had been using Roundup as an effective knockdown herbicide since 1979. Net-

working with Neville Ronnfeldt, Wayne kept up with the success of these trials and Ronnfeldt's experience with a new tillage system.

The initial problems with which Wayne Newton was concerned were in improving soil fertility, soil moisture, soil tilth, weed control, and sorghum regrowth. As he began to recognize the importance of stubble in water infiltration and moisture retention and to control sorghum regrowth with herbicides, other problems began to surface: the need for more information on herbicides, for better stubble-handling equipment, and for taking advantage of additional retained moisture. He set about acquiring greater knowledge and skill in utilizing herbicides, using new equipment, and in rethinking his cropping strategy.

To gain greater skill in using herbicides, Wayne Newton seized the opportunity to participate in the DPI and Monsanto-sponsored field trials in 1983 to 1987.<sup>14</sup> There were three objectives: (1) to determine Roundup's effectiveness in controlling weeds in a zero-tillage system, (2) to assess the soil- and moisture-saving differences among three tillage regimes: conventional, stubble mulching, and zero-tillage; and (3) to assess the benefits of the moisture saved as reflected in yields and gross monetary returns. Offset discs were used as the conventional method, and a field cultivator was used in stubble mulching. He also continued his own "experiments" with a reduced-tillage, stubble mulching system.

By 1987, Wayne had become convinced that conservation tillage had several major advantages (table 7.1). Capital and machinery costs were

Table 7.1. Results of DPI Tillage Trials (Summary)

	Conventional Tillage	Stubble Mulched	Zero-Tillage
1984 Barley			
Yield tons/hectare	3.08	2.80	3.39
Gross margin \$/hectare	183.34	167.73	211.37
1985 Barley			
Yield tons/hectare	3.40	3.76	4.24
Gross margin \$/hectare	138.72	167.55	185.79
1986–87 Sorghum			
Yield tons/hectare	8.70	8.80	8.60
Gross margin \$/hectare	752.30	767.60	719.50

Source: Peterson (1988b)

lower. Time and labor could be saved. Better weed control could be attained, and most importantly, higher and more reliable yields could be realized. This was primarily attributed to the greater retained moisture. As Wayne Newton put it: "We are dryland farmers. [The lack of] soil moisture is our greatest limiting factor" (Newton 1988a). Finally, grain sorghum was by far the most profitable crop.<sup>15</sup>

Since the early 1980s, Wayne Newton had become increasingly active in a local network of farmers "experimenting" with various conservation tillage techniques. He was also in contact with DPI officers, attended field days, consulted with chemical company representatives, and sought published material on conservation tillage. When the Conservation Foundation Information Center (CFIC) was established in Dalby, he was named to its board of directors.

Throughout the 1980s, while he was constructing a more satisfactory tillage system, the overriding objective was to prepare plant beds that would get good plant populations in a weed-free environment. By 1987, Wayne Newton had concluded that Neville Ronnfeldt's advice was sound: minimum tillage—one or two cultivations just prior to planting—(rather than zero-tillage) provided the best tilth and plant populations. "It is often easier and cheaper," he said, "and we have had better yields with a light cultivation or two prior to sowing at the end of the fallow period. It is the easiest way to apply our nitrogen fertilizer," (Newton 1988a) and it is the easiest way to control several species of weeds that are hard to control with herbicides. This is the tillage system that he has continued to use.

### *Further Action-Learning*

Between 1982 and 1988, when first interviewed, Wayne Newton had made several other adjustments. As much of the area is strip cropped to protect against flood damage, each strip is a multiple of the width of the planter. "Also, about one meter from one end of the planter, we have a blocked row. This gives a tramline effect in our crop with which to spray using a boom twice the width of the planter" (Newton 1988b). By this means, he avoids the need for marking and can accurately spray either day or night.

One of the most important adaptations involved modifying the planter so that it would operate more effectively in minimum tilled ground. Press wheels were added to improve seed-soil contact. The planter was modified so that stubble would more easily pass through without clogging. If the stubble was particularly heavy, even after cultivating to apply anhydrous ammonia, he learned that harrowing at high speed would usually provide adequate preparation for planting (while



another cultivation would usually leave the ground dry and hard). He learned not to worry much about wheel ruts because a cultivation after fallow usually leveled the ground.

Wayne learned that the surface mulch increased the organic matter in the top layer and that herbicides did not adversely affect the earth worms. He learned that it was increasingly necessary to use in-furrow insecticides to control soil insects. And, he learned how to use preemergence herbicides to provide weed control without damaging the commercial crop. By 1987, he was beginning to see second-generation weed species which were difficult to control with Atrazine and Roundup.

Rotation from summer to winter crops helped to control these weeds and diseases. Wayne Newton (1988b) pointed out, "Since summer cropping is more profitable, it is usually the greatest area. Following several successive sorghum crops, we double-crop back to a winter rotation with mostly chickpea or barley. Winter cropping is used to reduce summer grasses, such as *Urochloa*, which [is resistant to Atrazine]. After a winter cropping phase, we return to summer crops with a summer legume double cropped after harvest." Other summer crops, such as corn and sunflowers, with which different herbicides can be used, also can be planted when profitable to help control difficult weed species.

Conservation cropping, he believes, is a very complex technology, too complex for many farmers to understand and use effectively. Yet, when interviewed in 1988, Wayne Newton was highly satisfied with what he had been able to achieve with the new tillage system. He and his brother-in-law (Glenn Pumpa) were cropping 1,700 acres in two properties, and with double cropping they had attained a 120 percent cropping rate of the cultivated land. His wife was also involved in farm operations, managing forty cows on 350 acres of hill pasture and winter oats. Yearlings are sold to feed lots.

### *Environmental and Market Changes and Adaptive Change in the Farming System*

Although Wayne Newton, his wife, and Glenn Pumpa (brother-in-law) were still operating the same properties in 1995, the farming system had changed. Summer cotton had replaced grain sorghum as the principal cash crop, and the number of cattle had been cut to twenty-two breeders. Because of the marginal profitability of the cow-calf operation and the possibility of cropping some of the hill pasture, the cattle operation soon might be eliminated completely.

In the early 1990s, dryland cotton became twice as profitable as grain sorghum, but it had distinctive production requirements that took time to learn. One of the major requirements, Newton found, was moisture

throughout the full 1.5-meter soil profile at planting time. This placed a premium on planting cotton after a long fallow with stubble mulch maintained by using herbicides to control weeds.

The normal (ideal) rotation is winter wheat/barley followed by 12-month fallow into a zero-tilled summer cotton crop in October and November; double-crop (zero-till) wheat/barley in the fall, and after 6-month fallow seed a second winter wheat or barley crop; then long fallow back into cotton. Because of moisture requirements, only one-third of the cultivated area can be in cotton in any given year.

Drought interferes with this rotation, forcing the farm manager into opportunity cropping. If the planting window for cotton is missed due to lack of a full moisture profile, grain sorghum can be planted as late as January if long-range weather forecasts indicate the probability of sufficient rain. A sorghum harvest in May still permits zero-tilling double-crop winter wheat or barley, if moisture is available, and getting back into the rotation. If moisture for a crop is not available, Wayne would cultivate for fallow weed control (because cotton produces little stubble to be conserved).

Because lack of moisture has become an even greater cropping constraint, Wayne Newton has shifted gradually to more zero-till operations than had been his normal practice in the late 1980s. Cotton biology and the associated weed and insect regimes have led to changes in the use and application of chemical herbicides and insecticides. Because of the sensitivity of the cotton crop, Wayne has developed shielded sprayers for applying Roundup and mixtures to control in-crop weeds. Wayne has found it advantageous to contract with IPM consultants to monitor insect populations on cotton and apply insecticides as necessary.<sup>16</sup> Because of problems decontaminating sprayers in which 2,4-D was used, Wayne often uses contractors to apply 2,4-D mixtures in fallow weed control. Cotton is contract harvested.

New weed-specific herbicides have become available and have replaced older broader-spectrum formulations.

Management has become even more complex and sophisticated, especially on the financial side. With cotton trading on international markets, Wayne Newton receives cotton futures, which are faxed to him daily, and hedges risks of price swings by buying cotton futures. In 1989, Wayne Newton received a Bicentennial Travel Grant for one month and went to the United States where he visited farms in Texas, Kansas, Iowa, and Indiana viewing tillage technology. He talked with farmers and agents about the availability of crop insurance in the United States, and he visited the Chicago Board of Trade witnessing futures trading.

The marketing of new herbicides, the rapid development of cotton and its associated culture, and the importance of futures trading has brought further change in informational networks. The DPI field officers lacked information on dryland cotton culture and only recently have been able to provide information on the amount of moisture needed. As a result, networking with cotton growers has become very important. Chemical company representatives and contractors have become the first sources of advice on herbicides and insecticides, and private management and financial consultants are best able to keep up with rapidly changing market situations.

Wayne Newton articulates a vision of summer cropland dominated by zero-till planted cotton in strips alternating with fallow stubble of winter wheat and barley. In the winter, the strips are green with protective cereal crops. Unfortunately, this appealing landscape is ravaged by drought, which reduces the fallows to dirty stubble or even bare, black soil, and compels a mixed cotton and sorghum culture. The underlying objective is to maintain an economically and environmentally sustainable farm property for future generations.

### Rod Peterson and Construction of Conservation Cropping in the Killarney-Tannymorel Area<sup>17</sup>

Rod Peterson was born in 1951 and grew up on a farm that is part of the 1,000 acres in several blocks—650 acres owned and 350 acres leased—he and his father operate. The land, as Mr. Peterson (1988b) characterizes it, consists of “scrub Walloons based on fine grained sandstones with an average clay content of 54 percent, Forest Walloons on sandstone with 47 percent clay average, and Forest type soils based on Basalt with probably a slightly higher clay content. Slopes are in the range of 2 to 6 percent. “The area receives a 28-inch average rainfall, but the range is very wide. Summers are relatively humid, and summer crops of maize (corn), soybeans, sunflowers, sorghum do well when moisture is adequate.

In 1988, summer crops of maize and soybeans, with occasional crops of sunflowers, and winter crops of barley and occasionally chickpeas were the principal components of the farming system. He had forty-two head of cattle, as he explained, mainly to clean waterways of contour-banked fields.

#### *Early Dissonance and Initial Action-Learning*

In the 1950s, Rod Peterson’s father followed the common tillage practices of burning the stubble after harvest so that the stump-jump plow

could be used to plow the ground. Erosion of the slopes was such, however, that the senior Peterson responded to the arguments of conservation officers in the late 1950s and began to build contour banks.

When Rod Peterson joined the farming operation in 1967, his father helped him purchase the 200 acres on which he now lives. Soil conservation officers at this time were stressing that, in burning stubble, farmers were destroying organic matter. Rod Peterson (1988a) began to feel that "the nutrients in the stubble are being lost by burning . . . [and] should be returned to the soil as mulch." In 1970, he was among the first farmers on the Downs to purchase a chisel plow. This enabled him to gain experience along with other farmers during the 1970s about the importance of stubble in reducing erosion. Finally, in 1980 Rod Peterson and his father purchased a blade plow in order to improve stubble-retention capability. The chisel plow was retained as a light cultivator and to apply nitrogen.

Meanwhile, Rod Peterson and his father were among the first farmers to start using 2,4-D to control the broadleaf weeds contaminating the winter crops. When Atrazine became generally available in Queensland (about 1970), they started using it as a band spray along rows to control in-crop weeds and grasses. But, the experience gained in using postplant herbicides to control weeds in crops did not lead them to consider using herbicides to control weeds in fallow because cultivation was the common practice and herbicides were thought to be too costly.

Their perspective in 1980 on the management of fallow contained several elements. First, it was important to retain crop stubble on the surface instead of burning stubble, destroying nutrients, and leaving the ground exposed to erosion. Second, it was necessary to plow the ground to control weeds and to aerate the soil. A blade plow, which they had acquired, was an effective instrument for accomplishing both purposes. The Petersons were not yet aware that they were losing moisture through cultivation and accepted the progressive loss of stubble as unavoidable. Moreover, they had yet to recognize the advantages of better weed control, the labor and machinery costs saved by using herbicides, and the opportunities that moisture and labor savings would provide them.

### *Key Dissonant Event and Action-Learning of a New Tillage System*

The mounting pressure of rising farm costs in the early 1980s and the need to contain them were the principal events that encouraged Rod Peterson to begin thinking about the possibilities of cutting down on the number of trips over fallow fields to control weeds (i.e., a minimum tillage system). As he puts it (Peterson 1988a): "About 1983, . . . at a

time [that] I was really starting to think of doing some of my own experiments, a DPI fellow—Ken Bullen—came . . . looking for a site [for herbicide and cultivation trials]. And, I said, right, we'll do it there . . . in five or six acres."<sup>18</sup> With Tom Crothers of the Soil Conservation Branch consulting, Rod participated in a three-year trial of three different tillage strategies for fallow preceding winter barley and summer sorghum crops. Rod Peterson helped select the three alternative tillage practices: (1) conventional ground preparation with discs, (2) stubble mulching using blade and chisel plows, and (3) chemical substitution where possible. The results of the trials (see table 7.1) were as informative to DPI officers as they were to Rod Peterson and the other participating farmers.

The profitability of substituting Roundup for cultivation in summer fallow between winter cereal crops was clearly evident. For grain sorghum—the most profitable crop—the economic benefits of stubble mulching were equal to, or greater than, those of zero-tillage.

The significance of the time and moisture savings with zero-tillage led Rod to adopt a different management strategy with respect to double cropping. Although double cropping had been used on occasion to rotate from summer to winter crops and vice versa, there was rarely sufficient moisture for double cropping when fields had to be burned, plowed, and cultivated before planting. But, in the spring of 1984, there was considerable moisture in the ground after barley harvest, and Rod agreed with Tom Crothers' (1988) point of view that "if there is enough moisture to grow weeds, there is enough moisture to grow a crop." Rod immediately direct-drilled soybeans and obtained a fine stand. Although a late summer drought reduced the yield, the principle had been established. As Rod Peterson (1988a) puts it, "if you have [sufficient] sub-soil moisture [for another crop] when you harvest a crop, . . . there is little to be gained by . . . leaving it lie there. Might as well take advantage of it and put in another crop." In other words, when there is sufficient moisture, one could consider double-cropping for its economic benefits quite apart from whether a rotation was needed for agronomic reasons.

For Rod Peterson, the development and perfection of a conservation tillage system served the objectives of conserving and improving soil structure, saving moisture, increasing the opportunity for planting commercial crops, cutting costs, and improving the farm income. As Rod (1988a) puts it, "getting more money [through zero-tillage and double cropping] is pretty important for a start. We've been buying more country," and this would not have been possible with conventional tillage. Although the profitability of the new tillage system eased the financial burden of his recent land acquisitions, the desire for expansion was not

in itself a major factor in developing the new tillage system. Rod and his father had this aim since the mid-1970s when they bought the first block of 160 acres. Subsequent additions—70 acres in 1984 and 160 acres in 1986—simply fulfilled the goal. Indeed, they had planned ahead when purchasing equipment, buying equipment large enough to handle the additional acreage.

The immediate principal motive in trying zero-tillage was to construct a landscape that was consistent with his attitudes about preserving and improving the land. As he said (Peterson 1988a): “The only way people were double cropping summer crops into winter crop ground . . . was to . . . burn the stubble, and then plant into the black earth. I didn’t like doing that, and I . . . [wanted to save the moisture]. And, [I figured] there had to be a better way . . . of leaving soil in a good structural condition, instead of digging it up and drying it out.” Rod Peterson set about expanding his informational support network to help construct minimum and/or zero-tillage systems for his cropping system.<sup>19</sup>

The tillage system, which Rod Peterson constructed between 1983 and 1988, varied by season and seasonal conditions. For the winter fallow period between summer crops, Rod initially tried zero-tillage: using knockdown or residual sprays to kill weeds and/or sorghum regrowth and planting into untilled ground. But, he concluded that some surface roughness was needed on sloping ground before the onset of summer storms to aid infiltration.

Sorghum regrowth gave him serious problems. Because of relatively late harvests, he could not obtain sufficient regrowth after harvest to get a good kill with Roundup. The alternative was to go back to cultivating the regrowth or abandon the sorghum crop, and in 1988 Rod had chosen the latter alternative, relying instead on maize and soybeans.

With maize or soybeans, Rod settled on using herbicides, either knockdown and/or residual depending on weed conditions, at the beginning of the fallow. Near the end of the fallow, he cultivated once or twice to apply nitrogen and “give some surface roughness before summer storms” (Peterson 1988b). But, in 1988 Rod had not yet determined how much Atrazine to apply in order to provide sustained weed control without harming seed emergence in the next season’s crop.

For the summer fallow period between winter crops, Rod Peterson’s (1988b) system was “two or three early workings with a blade plough or chisel plough with a rod weeder attachment when the weeds were growing profusely. Later in the season when weeds are . . . [smaller], I use knockdown herbicides to [kill weeds] and conserve moisture until planting. [After losing preplant nitrogen] due to excess rain, . . . I now apply all . . . nitrogen fertilizer at planting.”

All opportunity (double) crops are planted zero-till to save time and moisture. With winter crops, a knockdown herbicide is applied immediately after harvesting the summer crop. Then the winter crop is planted with a Mason Conservatil, a high-clearance parallelogram type, three-bar planter. Phosphorous fertilizer and seed are put down together—and nitrogen, if needed—between the rows.

For summer opportunity crops, after one or two knockdown herbicide applications to control weeds and volunteer barley, maize or soybeans are planted with a modified Janke parallelogram planter with coulters and press wheels.<sup>20</sup> With maize, in-row insecticide applied at planting controls soil insects. In-crop weeds and grasses in maize are controlled with Atrazine applied after seedling establishment; with soybeans, Rod Peterson purchased shielded sprayers to apply Roundup or Sprayseed for weeds between rows at the same time that Fusilade is applied over the row to control grasses. In 1988, Rod had not yet worked out a system to apply a broadleaf herbicide on rows of soybeans.

With opportunity (double) cropping, Rod Peterson did not have any plan of crop rotation. Instead, judicious selection of summer (or winter) crops in the double-crop situations provided the weed-regime management that in earlier years required a crop rotation scheme. But, he was uncertain what the long-term effects of the new tillage scheme on soil structure and soil fertility might be. “A lot of farmers would say that putting country back to pasture and grazing to cattle would be beneficial to the soil structure . . . [and that] because I am cropping continuously I am flogging the country. I invite comment on my theory that opportunity cropping particularly with a high legume component would be as beneficial or more so than pasture” (Peterson 1988b).

### *Dissonance and Additional Action-Learning*

The new tillage and cropping system was accompanied by new problems. One of the most worrisome was the necessity of using toxic chemicals. A “healthy respect” for the new chemicals led Rod to build “good equipment for measuring, mixing, and applying chemicals . . . [including] chemical injector type measuring gear to obviate the need to pour and [possibly] spill chemicals” (Peterson 1988b). The spray rig he built has a 50-foot boom with foam markers, chemical injector equipment, hydraulic rams on each boom to negotiate contour banks, and spring-mounted support wheels to travel on rough ground.

Rod Peterson did not escape problems with perennial weeds, common to other farmers who were constructing conservation tillage systems. But, in the southern Darling Downs, he found through experimental trials that a flexible and relatively complex weed control



strategy worked effectively. The strategy involved rotation between summer and winter crops as well as switching from maize to soybeans, or other summer crops, and application of appropriate herbicides. One of the most troublesome was sorghum regrowth due to late harvests, early frosts, and insufficient regrowth to get a good knockdown with Roundup. As he says (Peterson 1988a): "[Compared with maize,] I was probably spending \$10 to \$12 an acre extra following the sorghum crop . . . just to get rid of the plant." Thus, he began to regard sorghum as a "noxious weed" and shifted to maize and soybeans as the principal summer crops.

Despite the conservation cropping system and its better crop-residue retention, erosion on sloping fields was still a problem, and Rod continued building contour banks until he had completely protected all the erosion-prone fields that he owned.

### *Environmental Change and Action-Learning between 1988 and 1995*

Since 1988, Rod Peterson has used zero-tillage with a variety of crops and under a range of seasonal conditions. These experiences have enabled him to develop considerable confidence in the utility and effectiveness of his system. As he put it in 1995: "In 1988, I was still trying to determine whether to cultivate, and how much. I'm probably past that stage now. I'm very confident in zero-tilling anything" (Peterson 1995).

The biggest change in his tillage and cropping systems has been brought about by a series of relatively dry years in the early 1990s. In the relatively normal seasons during the 1980s, the availability of subsoil moisture at the end of harvest made an opportunity cropping strategy highly successful. But, the dry years have made a fallow period necessary to build soil moisture before opportunity cropping. As Rod says (Peterson 1995), "[During] the last 4 years, its been doubtful whether we'd plant a crop after 6 months fallow."

Economic conditions have continued to favor summer over winter crops. Because maize, soybeans, and sorghum were the most profitable, the preferred cropping strategy has been winter fallow and a rotation among various summer crops to achieve weed control. On occasion when sufficient moisture is present following soybeans, Rod Peterson might double-crop barley if economic prospects seemed favorable. Because of the subnormal rainfall and the relatively greater drought resistance of sorghum compared to maize and soybeans, he has also had to reconsider his conviction that sorghum is a noxious weed. In the summer of 1994–95, he planted 300 acres of sorghum.

To handle the problem of sorghum regrowth, Rod built a self-propelled high-clearance sprayer. The sprayer enables him to travel



sorghum fields before harvesting and kill the sorghum with Roundup, thereby stopping all regrowth possibilities.

Dry weather and smaller profit margins have made necessary a short-range expansion into feeding beef cattle. Although Rod denies being a cattleman, he purchased yearlings last year from drought-stricken cattlemen. He ran the cattle on summer crop stubble and lucerne pasture. Although he did not like to graze the stubble, the weather was so dry that no erosion occurred. Also, because the sorghum crop was poor, he cut eighty acres for silage for the cattle. Then they were fattened on grain sorghum for 100 days.

Because of the difficult weather and economic conditions, Rod Peterson is doing more contract spraying and has also gone into contract haylage. Rod built a machine to wind-row lucerne for haylage, which another contractor processes.

Rod Peterson was elected chairman of the local Landcare Committee. The Committee used a \$20,000 grant from the Commonwealth Government to enable Rod to design and build a zero-till planter. Built on a chisel-plow platform, the planter has disc coulters, openers and press-wheels. The machine is available for anyone in the area to use. It won the committee the 1993 Queensland Landcare Award and made them eligible to compete for a Commonwealth Award.

Rod Peterson is satisfied with the tillage system he is now using. He believes it is efficient and enables him to save both soil and moisture. He is pleased with the landscapes he can construct in normal years. In dry years, the bare earth, which offends rather than attracts him, inevitably protrudes. But, the very dryness, along with the contour banks, protects the fields from damaging erosion.

### Colin Bell and Reconstruction of Conservation Tillage in Clifton<sup>21</sup>

After completing the tenth grade in the mid-1970s, Colin Bell started farming in partnership with his father on the 600-acre family farm. The family partnership, which also includes Colin's brother,<sup>22</sup> expanded operations with the purchase of a 300-acre block in 1981 and another 700 acres in 1991. The average rainfall on these properties on the eastern Downs is 27 to 30 inches, primarily in the summer, but is quite variable. The soils are black, cracking clay vertisols of basaltic origin.

The Bells are primarily grain growers but raise an average of twenty to forty head of cattle annually, which graze waterways and forage harvested crops. Summer crops of grain sorghum, maize, and sunflowers are the principal basis of the cropping system. Cool and damp November nights,

which slow the ripening of wheat but not barley, favor the latter as the principal winter crop. Rotations are primarily governed by weather conditions and the availability of moisture. Up until the early 1970s, the Bells' farmed conventionally, plowing fields with the sundercutter and cultivating the fallow to control weeds.

### *Early Dissonance and Action-Learning*

In the late 1960s, the Bells became sufficiently concerned with the erosion of their fields that they began building contour banks. But, soon they could see that the contour banks were not providing complete erosion control, and 2 or 3 years later they acted on the notion, relatively new at the time, that they should try to keep the crop residue on the surface to protect and enrich their soils. To do this they purchased, in the early 1970s, one of the new chisel plows, which could handle stubble, and stopped the regular practice of burning straw.

Colin and his father had also started using 2,4-D as a spot weed control, but cultivation remained the general method of controlling weeds in fallow, and it never occurred to them to use herbicides as a general weed control strategy. As Colin Bell (1988) recalls: "[About 1976] a local stock inspector said to me that in America they don't work the ground, they spray it. And, I thought what a [crazy] idea that would be. I hadn't heard anything so ridiculous in my life."

### *Key Dissonant Events and Action-Learning of a New Tillage System*

The biggest difficulty in satisfactorily controlling weeds with cultivation was wet seasons, which prevented cultivating in a timely manner. As Colin (Bell 1998) put it: Because of the high weed population after a rain, farmers normally are "in a panic to get out and kill them. Early on, . . . some paddocks got away from us. About 1980, when Roundup came out, we just got the plane and sprayed them, . . . and I said, 'Boy! This is something that is going to kill the weeds.' "

Moreover, "people believed that if you didn't work the black soil it would get hard. So, after [the 1983] harvest the ground was too wet to work; we sprayed probably the heaviest soil we had . . . and we couldn't . . . work it for 2 months. When we went back, we found the header tracks had all loosened. So, we knew then that the ground didn't have to be worked" (Bell 1988). The twin discoveries that they could satisfactorily control weeds with herbicides and improve soil structure triggered a commitment to change their tillage system.

Unlike farmers who perhaps made a definite decision to make a clean break with conventional tillage and henceforth develop a conservation tillage system, the Bells constructed their present system one step at a

time. As Colin Bell (1988) reflects: "Its been a gradual thing. I remember Neville Ronnfeldt saying in a Toowoomba meeting about four years ago, that the hardest decision is to make up your mind to do it. I got the impression that he said, right, you're going to do it and that's it. But, we've not been as radical, or as game, or had the equipment to do it. Each year we see another advantage that gives us another opportunity to use . . . [some new tillage technique]."

Once the Bells had started on the path of using chemical substitution, however, as Colin Bell (1988) remarked, "we kept our eyes open, and there was always plenty to read" in the farm papers. "We never sat down and [decided], we're going into minimum tillage. Each little thing we have tried has enabled us to see that there are definite advantages with it."

An important aspect of keeping their eyes open was networking—observing and talking—with other farmers about their experiences. The Bells met regularly at Roy Noller's place<sup>23</sup> with several other farmers and professional advisors to discuss tillage strategies and the success or failure of each new technique.

In 1985, Colin Bell received Elders (farm supply firm) sponsorship to travel to the United States to see what was being done in conservation tillage on the Great Plains as well as a trip to the CFIC meeting in Dalby that year. Colin became active in the Queensland Grain Growers Association, and the contacts with other grain growers were opportunities to pick up and check out ideas.

### *Further Action-Learning*

Having been alerted through the network that they were losing moisture through cultivation and that another crop could be planted after harvest using the available moisture, a signal event moved them to try zero tillage. At Easter time in 1983, the Bells applied fertilizer and were waiting for a planting rain. But, no rain came, and in May when it was time to plant barley, they "discovered that there was still moisture in the ground . . . about three inches down. . . . So, we replaced the shears with points and put the barley seed in the ground about five inches deep and got a perfect strike. . . . So, that was the start of realizing just how much moisture we waste" (Bell 1988).<sup>24</sup>

This led the Bells to pay increased attention to the amount of moisture in the soil profile. They began using a moisture probe to measure available moisture, along with more traditional methods of a digging hoe and hand test.

Along with other farmers in the area, Colin Bell sprayed sorghum regrowth for the first time in 1984. It proved providential because the

winter turned wet, and his regrowth was killed, whereas his neighbors who did not spray had regrowth out of control. The next spring he applied anhydrous ammonia with the chisel plow before planting sorghum in the soft, untilled ground.

The Bells quickly found that they had to modify their spray equipment, and over a period of time, they learned how to utilize herbicides effectively and efficiently. "We started with a boom sprayer with one pump and one set of nozzles," says Colin Bell (1988). "Now, we have 80 and 120 degree nozzles. The first time we sprayed we didn't know how much water to use. . . . Then, we found that we needed more water. We used to think that we couldn't use anything [other chemical] with Roundup. Now, we know you can use atrazine if you have the proper wetting agent. So, gradually we've learned how to effectively use chemicals, usually by finding out that something didn't work and then mixing other chemicals to get the job done properly."

The progressive construction of an effective conservation tillage system, however, also required purchasing new equipment. A year ago, the Bells purchased a Gyrat airseeder, which enables them to apply bulk urea (nitrogen) while planting into stubble (zero-till). They had put off buying a new planter until Gyrat came out with a sectional design that enabled the planter to operate on uneven ground. Because the Gyrat requires more tractor power, they purchased a larger (160HP) tractor. In the fall (May) of 1988, Colin Bell planted his first field of zero-till barley.

Between 1980 and 1988, the Bells had shifted from a modified conventional tillage, using the chisel plow (sometimes a sundercutter) and working the fallow ground four or five times before planting, to two or three workings and two sprays. The sundercutter had been retired. Although they recognized that cultivation brings new weed seeds to the surface and destroys moisture, several problems still made zero-till in the long fallow situations rare. One was the presence of nutsedge, which the Bells were not yet able to control with herbicides, and another was the necessity of applying large amounts of nitrogen, especially for maize, and the difficulty of doing this with their present equipment in one pass at planting time. Early and prolonged winters in recent years have also increased the difficulty of adequately controlling sorghum regrowth and volunteer sorghum with herbicides.

Meanwhile, they had overcome any fears of using chemical herbicides, and they were becoming increasingly competent in weed management with chemicals. In 1988, Colin Bell concluded: "Looking back 3 years ago, I wouldn't have thought that I would have been doing as much zero tilling as we are. . . . The number one idea is to have a clean paddock [of weeds]; how you arrive at that, I guess, determines

your operations. . . . [However,] I think it will be quite a while before we are [only] zero tilling even though that would be the best way to go.”

### *Drought, Markets, and System Adaptation*

The four-year drought on the eastern Downs hugely affected the Bells’ tillage and cropping operations. When crops could be planted, they often failed and were used for forage rather than harvested. Whether harvested or not, the stubble cover was limited and weathered quickly. Low moisture levels inhibited experimentation with new crops or tillage operations. Poor crop yields translate into low farm income, which discourages the purchase of new, more efficient, zero-tillage equipment. In 1995, the Bells were still using the same complement of machinery that they had in 1988. The prolonged drought, in other words, had stifled further tillage system construction.

During the intervening years, several new weed species have become dominant, but Colin succeeded in controlling them with herbicides. Thus, his competence in using herbicides has increased, although the pattern of usage has remained much the same. However, Colin has now become recognized by other local farmers as an “expert” to be consulted when spraying time arrives.

In 1991, just as the dry years were beginning, the Bells purchased another block—700 acres. The larger area could be cropped with their existing equipment because of the efficiency of their trash planter (airseeder) and larger tractor. In this respect, Colin Bell recognized that he had become more committed to using the zero-till planter even though he continued to apply anhydrous ammonia independently with the chisel plow.

Because of the crop failures and the necessity of using whatever grew for fodder, the Bells periodically increased the number of cattle to forage the crop. These increases, however, were temporary or emergency measures. Even though the farm purchased in 1991 had a larger acreage of pasture, drought restricted the growth of pasture grass and did not encourage the Bells to consider permanent expansion of livestock.

Colin Bell’s image of a “good” farm landscape has changed substantially in the past 20 years. As he recalls (Bell 1995):

When I left school and . . . [began to] farm, if you had a good paddock and kept it black . . . the better it was. Any chance of something on it you would get out and cultivate it. . . . [But,] I was coming back from Gladstone in the mid-eighties, and near Dalby . . . [we passed] a big tractor working with . . . probably a 40-foot cultivator, and I said to one of the guys on the bus: ‘Gee, that looks good. Doesn’t it?’ And, he said, ‘That’s ugly. Look at that! Not a bit of trash on the ground. What protection have

you got?’ And, I thought a really nice, flat, black paddock was beautiful. But, he thought, no, that’s terrible. I guess I could see what he meant. And now, if I drove over the hill and saw stubble cover on all our paddocks, I’d think: Right, that’s what I was aiming to get, rather than seeing them all bare. . . .

When we were developing this farm and the Spring Creek farm, we . . . [pulled] all the interior fences and brought in a contractor and put in broad-bank contour banks. This changed the landscape of the farm: . . . no fences up and down the hill and . . . [the ground] worked on the contour. . . . On the creek flat side, we’ve pulled up the fences and leveled the ground, taken out the gullies and ridges where the water used to jump through the fence line, and now we are looking at strip cropping. . . .

I think . . . you can judge a farmer by the roadside as you drive along. Because if a guy has got burr and rubbish between the bitumen and his fence there’s a pretty good chance he’ll have it throughout the farm as well. . . . There’s no excuse for having weeds on your farm because they are easy to kill. A clean farm means a lot to me. Slashed waterways: that’s something I think every farmer can do better . . . maintaining waterways.

### Roy Noller and Reconstructing Conservation Cropping in Nobby<sup>25</sup>

In 1979, when he was in his mid-forties, Roy Noller purchased Brookstead, the home place that had been in his mother’s family since 1910. He purchased an adjacent block in 1982 and now operates a 700-acre property. In 1988, his son—Timothy—was in college but helped on the farm, and Roy worked also with a son-in-law who had a property nearby. They worked the properties together, sharing machinery, grain storage, and drying equipment.

The soils are black, cracking clay vertisols of the eastern Downs. As Roy Noller (1988) put it, the general objective in farming is “to grow the crops that are most profitable . . . with the machinery that we have. Then we’d like to get a rotation into our cropping that would solve our weed . . . and insect problems, and also mindful that [some] crops will give us some ground cover and protect our soil.” Summer crops of sorghum, corn, and sunflowers were the mainstays of the farming system in 1988 with winter barley when rotation is necessary. Chickpeas, a legume, is a profitable “opportunity crop” that is used in changing rotations. In 1988, Roy Noller did not have any cattle or sheep.

#### *Early Dissonance and Adaptive Conservation Actions*

During the 1950s, Roy Noller and his father were among the first to become concerned with soil erosion and were early innovators in using

new ideas in soil conservation and weed control on the home place. Roy Noller (1988) still vividly remembers the day in the early 1950s that his father “came home from somewhere and said [to us,] ‘We’ve got to look after this soil, and we’ve got to make some contour banks.’ We . . . designed drainage banks, instead of contour banks, because we didn’t want to farm on crooked lines. . . . But, they worked,” partly because the slopes were gentle, and they were also saving stubble as much as possible. Contour banks were built by his uncle on other areas of the property in 1974 after the shire was declared an Area of Erosion Hazard.

Wild radish, turnip, thistle, and buckwheat were problems in wheat and barley, and in 1952 the Nollers started using 2,4-D sprays to control these weeds. As Roy Noller (1988) recalls: “We had an antiquated boom sprayer with round nozzles mounted on the back of a truck. If a nozzle didn’t work, we would punch a hole in a penny to replace the part.” But, they never considered using herbicides to control weeds in fallow because they were grazing the volunteer crops and weeds with livestock and because the normal practice in weed control was cultivation.

As time went on, Roy Noller gained more experience in using chemical sprays, but when he returned to Brookstead in 1979, he still used only herbicides for in-crop weed control. That year, the rainfall was unusually high, however, and on one paddock that was too wet to cultivate, he tried controlling weeds with herbicides. But, this was a salvage operation, and Roy did not think of spraying as a regular substitute for cultivation. Instead, the purpose was to knock down the weeds so that a cultivator could do a better job.

Although they plowed and tilled the ground in conventional fashion in the 1950s, Roy Noller’s father (and brother who followed his father on the home place) believed that crop residue helped build the soil, and they never burned the stubble unless it was absolutely necessary. “Trash farming” thus was an idea that they readily adopted, and when Roy Noller purchased Brookstead in 1979, he purchased a bunyip—deep tillage plow—and a better boom sprayer and continued trying to save stubble.

### *Dissonance and Initial Action-Learning of a New System*

With his background in conservation—contour banks, limited stubble mulching, and herbicides—the shift in orientation to using herbicides as a substitute for cultivation in fallow weed control was a relatively undramatic additional step in saving soil. As Roy Noller (1988) recalls: In 1981, Mitch Hook, the field representative with ICI, “approached us, and we started to do trial work . . . [with herbicides]. From then on, I



doubt if I could be called a zero-tillage man, but I [was doing] reduced tillage or minimum tillage as the opportunity allowed it." It was another, but significant, step in "rebuilding the fertility of the soil, and . . . [in] keeping the [soil] there" (Noller 1988). It did, however, require learning how to use the new chemical herbicides, learning new spraying techniques, and purchasing some new equipment.

Initially, Roy Noller (1988) was "very wary of chemicals . . . especially those with long residuals," like Atrazine. Mitch Hook, and later Jim Hitchner (an agronomist with Moree Seed Company) would recommend trial mixing several herbicides to control particular weed problems. "They organized little cell groups [of farmers who were trying different spray techniques].<sup>26</sup> Periodically, we'd sit down around this table and discuss [what has worked and what hasn't and suggest solutions]. It was probably in these discussions and the feedback that we learned the most about mixing chemicals. For instance, adding sulphate of ammonia with Roundup was something we learned this way, and now we use it regularly. Or, dicamba with Roundup, when you can't use 2,4-D." Roy set aside a plot next to the house for these farmer-network experiments.

The experience gave him confidence in using chemicals, although he would rather not use them if satisfactory alternatives were available. Roy Noller learned to select particular herbicides based on the specific weeds to be controlled, the crop and its stage of growth, and the future plan for the paddock (i.e., whether it would be fallowed or possibly double cropped). These complications and the uncertainty of future conditions make the use of herbicides a much more complex management decision than cultivation. But, herbicides can be used in wet conditions when cultivators cannot be used and can help salvage the weed control and planting program.

Roy Noller has partially substituted chemical herbicides for cultivation. In a winter or summer fallow, he cultivates and sprays twice each. But, he uses crop rotations as well as cultivation and herbicides to control weeds, insects, and diseases. Because of the early winters on the eastern Downs, controlling sorghum regrowth is a problem for Roy, and he often resorts to ripping the ground so that frost can kill the exposed roots.

Rotations help cut the cost of weed and insect control measures, and by introducing legumes in the rotation, Roy aims to reduce the fertilizer bill. In 1988, the rotation plan was sorghum to corn to double-crop chickpeas. By fallowing the following summer, controlling the weeds, and planting a winter crop of barley, Roy gains control of the hard-to-kill summer weeds and can return to summer crops.



The sprayer, which he had purchased in 1979, was still adequate in 1988, but Roy had to learn how to use it more effectively with different types of nozzles—80 and 120 degree—and various application rates per hectare. In 1981, Roy purchased a new John Deere planter, which he has modified by removing tines and changing the spacing to improve trash flow.

### *Drought and Tillage and Farming System Adaptations*

Most of the plans and dreams that Roy Noller had in 1988 turned to dust during the following dry years. Through 1995, 1992 was almost the only good crop year the Nollers had had since 1988. In 1994, Roy took a job with Pioneer Seed Company and is operating Brookstead in partnership with his son Timothy, who graduated from college and returned to the farm.

In the dry years, summer crops that were planted did not often reach maturity and were either grazed, cut for silage, or baled for cattle feed. The Nollers turned to “opportunity” feed lotting of cattle to utilize the corn and sorghum forage. Under Queensland regulations, feedlots of less than fifty head do not have to be licensed, and for several years, they have fed a half dozen lots of twenty-five to forty-nine head of cattle.

The tillage system, as Roy Noller (1995) wryly observes, has been reduced tillage. Most of the property this year was only ripped with a bunyip. Where normally they would change the oil in the tractor four or five times a year, they went 12 months last year with only one oil change due to drought and lack of cultivation of any kind. Despite the lack of tillage, the soil is almost black because there has been little stubble cover. For summer crops, the Nollers continue to apply nitrogen with chisel plow and then plant, rather than to do both operations in a single trip over the field.

Dry seasons and the risk of not having sufficient moisture to get plant emergence has led Ray Noller to change his strategy in using herbicides. Instead of using a preemergent herbicide, like Atrazine, he has shifted to using postemergent sprays (e.g., Dual and Roundup) after they have a stand of sorghum or corn. By not using spray before they need to, they keep costs down. Also, to hold down out-of-pocket costs in controlling fallow weeds in dry seasons, the Nollers sometimes feel it is more cost effective to cultivate than to spray weeds.

Rotations have been abandoned, and crops are planted on an opportunity basis (i.e., whenever sufficient moisture is available and the long-range forecast is for enough more moisture to raise a crop). In fact, the lack of summer rainfall in recent years has forced the Nollers to rely on winter barley as the principal cash crop.

With respect to his land, Ray Noller's (1995) hope is:

to leave [the land] better than I found it. . . . We've improved the tilth of the soil. We've improved the protection of the land with contour banks and some strip farming. . . . We've tried not to be miners, but farmers adding to the soil the nutrients that the crops need. . . . [By contrast with earlier years,] we have no trouble at all producing wheat with 13 percent or 14 percent protein which is actually quite high for this area. . . . We don't have any shortage of N[itrogen], and we're working with the micro-nutrients. . . . In 10 years, Timothy [Ray's son] can say father didn't do such a bad job trying to get the land back to its natural shape. Actually, we have a small area, [which has never been tilled,] that we're using as a [comparison with land in which we have restored the fertility.]

### Neville Heard and Reconstructing Conservation Cropping and Farming in Warwick<sup>27</sup>

In mid-1981, Neville Heard moved with his family from a sheep-grazing property in Victoria to the 700-acre farm he now operates on the eastern Downs. The property has rolling hills and black, basaltic clayey soils.

When first interviewed in 1988, Heard's farming system was primarily based on summer crops of sorghum and soybeans and a winter-crop barley, although sunflowers, navy beans, and chickpeas were also occasionally included in the rotation. The normal pattern was sorghum for 3 years, barley for 2 years, and then soybeans followed by sorghum. Neville Heard kept fifty head of cattle primarily to keep the waterways clean and make an occasional profit.

Because he had only been farming the property for 7 years, the farm equipment was limited to the implements Neville Heard had purchased to establish the conservation tillage system he established when he began—tractor, chisel plow, trash seeder, slasher, boom sprayer, and scarifier with anhydrous ammonia attachment.

#### *Early Experience in Victoria*

While grazing sheep in Victoria, Neville Heard planted winter oats for grain using conventional tillage. Rye grass and wild oats were problem weeds in winter crops, and he decided to determine whether he could control them with herbicides. Neville borrowed a boom sprayer from a relative, and on the advice of his brother-in-law sprayed the oats with Avadex and Treflan. Although this did not kill all the weeds, there were only one-half as many as in an unsprayed test strip. This convinced Neville that herbicides could be used effectively to control in-crop weeds in small grain.

### *Initial Strategic Decision and Dissonant Event*

When he moved to the grain-growing property on the Downs, Neville Heard realized that the farming practices, which he had used in Victoria, would not be satisfactory, and he decided he would have to learn the best farm management practices common in the area. He found that the previous owner had built contour banks on the steepest slopes and had been stubble mulching to save soil. Neville decided that he should also practice stubble mulching and purchased equipment that would enable him to do so. He put in his first summer crop using a Morris chisel plow, trash seeder, boom sprayer, and slasher.

Realizing that he lacked the knowledge and skill to grow crops successfully with a stubble-mulch system, Neville mounted an intensive search for literature—books, pamphlets, leaflets—from the DPI and other sources that he read. He expanded his network in other ways too, going to field days and seeking the advice of neighbors, especially the successful ones like Rod Peterson at Killarney. The more Neville learned about conservation tillage, the more committed to the system he became.

Within 2 months of his arrival in the spring of 1981, a big storm occurred that resulted in considerable erosion. This convinced Neville that he had a problem with “wash-aways,” and he decided that expansion of the system of contour banks was essential. He immediately contacted the local Soil Conservation Branch officers and requested the preparation of a farm conservation plan. Four months later in mid-1982, he had a plan of conservation works and began building waterways. The contour banks on the most erosion-prone areas were completed in 1983. In 1985, he completed the contour banks on the other sloping areas.

### *Dissonance and Continued Action-Learning*

Because the rain event strengthened his interest in soil conservation, Neville Heard also tried strip cropping winter barley and summer sorghum in 1982. But, he saw that in itself this was not a satisfactory erosion-control method. Moreover, strip cropping was ineffective in controlling weeds that migrated from one strip to another.

His experience in cultivating weeds convinced Neville Heard to begin relying more on herbicides for weed control. He put the defining cognition this way (Heard 1988): “I was out there with the tractor working to kill weeds all the time. I realized that I was working it too soon, and more weeds came up. Then I worked it again. We worked it after harvest and then probably once a month . . . about five cultivations and six with planting. That’s when I thought well there’s got to be a better way

than this . . . and started doing a bit of spray. . . . With a spray or two . . . we can get back to maybe three workings [with the cultivator].”

As he contemplated the prospects of minimizing cultivation, the possibility of zero-tilling became more and more appealing. In 1985, Neville attended a field day at the Hermitage Research Station, and they had, as he said (Heard 1988), “a trial on no-till, conventional till, and burnt stubble over quite a few years. A graph showed that the no-till had the highest yield. And, I couldn’t believe it. . . . I went back and asked about it. They had another field day in 1986, and the no-till one still had the highest average yield. That sort of thing triggers my mind.” Moisture saving, which increased the prospect of opportunity cropping, was also an important factor in shifting toward zero-tillage.

To handle the work more easily and to operate with more trash on the ground, Neville decided to upgrade his equipment. In 1986, he purchased a larger tractor, a bigger trash seeder, and a scarifier on which he mounted a tank to apply anhydrous ammonia. In 1988, he purchased a Janke zero-till planter to facilitate double-cropping soybeans into barley stubble.

In the summer of 1986–87, Neville Heard tried his first zero-till crop: Soybeans were planted straight into barley stubble. The good performance encouraged Neville the next season to try zero-tilling sorghum into the previous year’s sorghum stubble. Although he had no trouble controlling weeds with Primextra, Dual, and Tordon, putting fertilizer on the sorghum stubble with the scarifier applicator was difficult.

Neville Heard’s strategy has been to experiment on a small basis and a small risk to find out what works for him. This is especially the case with herbicide application. Over the years, he has experimented with applying less and less herbicide.

I’ve been down to 300 ml per hectare killing black oats, and might have been able to go lower than that if I had put it on at the right time of day so that it would have had time to soak in. . . . They tend to think with Sprayseed that the best time to use it is in the evening or at night because it has all night to get into the plant.

Our main problem with spraying is that every time you get out with the boom sprayer, the wind comes up . . . . Maybe we should go to a night-time spraying when there is no wind. I find that most weeds you can deal with. Its just that you can’t spray them at the right time. (Heard 1988)

Variable weather conditions often invalidate comparative evaluation of different herbicides. But, Neville shifted gradually to spraying with Sprayseed herbicide to control weeds before planting rather than cultivating, which destroys stubble and puts more weed seed where it can germinate. Sometimes the presence of weeds that are tough to kill, such as European

bindweed, make cultivation necessary. In 1988, he had not yet solved the problem of sorghum regrowth with herbicides, although he knew that 1.5 litres of Roundup per hectare when regrowth was 8 inches high was recommended. Neville had also found that Roundup and Fusilade were effective weapons in the continuing battle with johnsongrass.

Although Neville Heard has learned to make increasing use of herbicides despite his concerns about using chemicals, he resists using insecticides because of the injury to insect predators. He has become a strong supporter of integrated pest management and uses methods recommended by the DPI to monitor midge and heliothis levels on sorghum fields. He also tries to plant his sorghum at the same time that others in the area are planting to reduce the risk later of midge infestation.

Cropping experience and soil testing have led Neville Heard (1988) to make increased use of nitrogen fertilizer. "When we . . . [came here], we started off with thirty units of nitrogen an acre, and now we're up to fifty-five. That's for winter crop. For summer crop, we're up to the range of 100 units of N[itrogen] per acre compared to the fifty units per acre we started with." Moreover, he has made increasing use of leguminous crops—winter chickpeas and summer soybeans—which put nitrogen in the soil. Unfortunately, the difficulty in controlling weeds in chickpeas limits their use, but satisfactory control of weeds in soybeans is possible with herbicides. The preference for soybeans is strengthened too because sunflowers, its summertime competitor, suffer from risks of bird damage.

### *Drought, Markets, and System Adaptation between 1988 and 1995*

The dry years after 1990 compelled Neville Heard not only to change his tillage system but his farming system as well. The drought increased the movement to zero-tilling summer crops with the new Janke planter partly to conserve moisture and partly because there is little need for fallow cultivation because weed growth was minimal. To increase efficiency of no-tilling, Neville purchased tanks to mount on his tractor so that he could plant and spray at the same time. The shift to zero tillage was made despite his preference for working the ground once or twice during the fallow. However, drought interrupted movement toward zero-tillage of winter crops because there was insufficient moisture, and with the greater importance of cattle, Neville has become more interested in growing winter legumes, such as cowpeas.

The tougher economic climate encouraged experimentation with lower and lower rates of herbicide application, but failures in controlling weeds with low application rates convinced Neville to settle on application rates sufficiently high to insure weed control. However, he

has learned to adjust rates to the size of the weeds that must be controlled. Weather conditions often frustrate the optimum application of herbicides, and untimely wind is a major frustration. As Neville Heard (1995) explains: "The day I want to spray, a southeasterly wind [invariably] blows, and that can happen for weeks, and you think it would be easier to plow that paddock. . . . I've gotten up at half past three o'clock in the morning [to spray], and it's still blowing. . . . Eventually, you put the chemicals in the sprayer; . . . probably more chemical because you haven't sprayed on time," and spray despite the hazard to adjacent crops. At other times, the weather is so hot that the spray evaporates almost as soon as it hits the crop, and sometimes the water from the bore wells has contaminants and cannot be used.

With the drought, Neville Heard has shifted his farming system from primary reliance on the sale of grain crops to cattle. He expanded the breeding herd to fifty cows and has been operating a small feedlot. The grain, which he has managed to grow, and forage are fed to the calves and purchased yearlings. To prepare his own feed, Neville purchased a hammer mill. If feed is available each year, Neville fattens and sells three lots of about forty-nine cattle each. He regards this change in his farming system as a permanent adjustment, which he hopes to expand. It is not only more profitable but is also less risky and better suits the moderate size of his farm.

The need for cattle feed convinced Neville Heard to begin growing millet and forage sorghum. Maize for forage and/or grain is an occasional option. Sunflowers remain as a profitable summer cash crop despite the threat of severe bird damage. Dry years have prevented growing much winter crop.

Ever the optimist, Neville Heard (1995) views the drought as having positive environmental benefits "because we're not cropping every acre. We've changed our system . . . [to more livestock.] Not cropping over hill country that has been badly eroded. . . . That must make the land better. . . . I think the drought is sort of nature's way of giving the country a rest." In particular, Neville believes his farming system, as he has developed it using contour banks and waterways, retaining stubble, and increasing the use of pasture and legumes for livestock, is much better for the farm and the landscape than the system he started with.

## Social Construction of Conservation Tillage and Cropping Systems in Australia: A Summary

### *Context*

In response to changing world-market incentives, farmers in the 1950s and 1960s on the Downs began converting pasture and rangeland to

grain growing. Using conventional plow culture, farmers were immediately confronted with massive erosion due to the intense summer storms and highly erosive soils. Aided by soil conservation engineers, a few innovative farmers began changing the farm landscape by building contour banks and waterways and planting strip crops. These steps were only a partial solution because wind and water still caused substantial erosion even on treated slopes. By the end of the decade, leading conservationists began to advocate the retention, rather than the burning, of crop residues, and Queensland governmental authorities took steps to access the global resource network in the United States and evaluate improved stubble-handling equipment—chisel plows and trash planters.

*Initial Dissonant Events, New Tillage Goals, and Action-Learning*

Perceptive farmers on the Downs rather quickly recognized the soil and moisture losses and deteriorating soil structure occasioned by conventional tillage. The advantages in soil tilth and moisture retention of retaining stubble appealed to them, and in the early years of the 1970s they began to acquire chisel and blade plows and to experiment with stubble retention (rather than burning it). They quickly found they had to build or purchase planters with better stubble-handling capability if they were to plant into stubble. But, most farmers continued cultivating their fallow ground to control weeds. Multiple cultivations during long fallows quickly destroyed the stubble. Trash planters thus remained a relative novelty.

Meanwhile, farmers raising wheat and barley were struggling to control in-crop weeds and began making increasing use of herbicides. Although they gained competence in this application, they did not consider using chemicals as a substitute for cultivation to control weeds in fallow.

Once again the impetus for a more radical change in tillage goals and practices occurred as a result of reaccessing the global network in the United States. In the mid-1970s, through publications and visits to the United States, soil conservation officers became familiar with no-tillage cropping. With the assistance of the DPI, Monsanto sponsored trials of reduced-tillage and zero-tillage on cooperating farmers' fields in 1978 and 1979. Other chemical companies soon followed suit.

Innovative farmers (for example, Neville Ronnfeldt and Hector Tod) quickly perceived that they could save labor and tractor fuel as well as crop residue and moisture by substituting herbicide application for cultivation. They began experimenting with the substitution of herbicides for some or all of the fallow cultivation.

With these incentives, innovative farmers began to change their cropping systems. Although the common practice had been a short fallow



between annual winter or summer crops and a long fallow when shifting from summer to winter crops, farmers began to “opportunity crop” (i.e., double-crop winter and summer, or summer and winter crops when sufficient moisture was available to get up the crop). Meanwhile, they continued to modify and develop planters that were better suited to soil conditions on the Downs.

### *Key Dissonance-Creating Events and Constraints*

In the early 1980s, a combination of wet seasons, which made timely weed cultivation impossible, and economic pressures to reduce machinery and fuel costs compelled other farmers to try to salvage their fields by substituting herbicides for cultivation in fallow weed control. Although Rod Peterson, Wayne Newton, Neville Heard, Colin Bell, and Roy Noller benefitted in constructing their tillage systems from the experience and advice of consultants and pioneers like Neville Ronnfeldt and Hector Tod, each had to construct a tillage and cropping system that he could manage successfully on his farm.

Differences in soils and climate affected the performance of available equipment. Most had to modify equipment, especially planters, so they would perform to their satisfaction. Each had to become more knowledgeable of soil nutrient and crop moisture requirements as well as weed species and methods of herbicide application. With this information, they modified their cropping systems, and they learned how to use rotations to facilitate weed control.

### *Different Motives, Similar Outcomes*

Although use of stubble-saving equipment was the initial step these innovators made into conservation tillage and cropping, it was made for different reasons. For Ronnfeldt on the western plains, moisture saving and better soil tilth triggered the shift. On the eastern Downs, attempts to save soil by building contour banks and saving stubble (stopping burning) were the motivation to acquire stubble-handling equipment and change cultivation practices. Once this step was made, acquiring trash planters and learning how to use them necessarily followed. For all of these innovators, the substitution of chemical sprays for cultivation in fallow weed control was the system change that inaugurated construction of a radically different tillage and cropping culture. The new culture of agriculture was constructed in a sequence that involved the substitution of herbicides for two or three of the fallow cultivations. Then they tried zero-tillage, primarily in order to double crop. Eventually, drought and the desire to save moisture induced nearly all of them to no-till as a more regular practice.



### *Drought and Tillage and Farming System Adaptation*

The sequence of dry years after 1990 highlights the importance of environmental conditions for tillage and farming systems. The response to drought, however, has been shaped by perceived cost-benefits of alternative courses of action. The imperative of saving moisture, as well as the poor growth of winter weeds, impelled Ronnfeldt, Newton, Peterson, Bell, and Heard to shift from the reduced tillage system often used in growing summer crops in 1988 to more regular use of no-tillage. In this summer rainfall area, drought made the growing of winter crops infeasible. Because of the poor crops and cash flow in the dry years, however, Roy Noller and his son now rarely use herbicides to save out-of-pocket costs.

The difficulty of obtaining good yields in dry years impelled all the innovators to make changes in their cropping and farming systems. The rarity of having sufficient moisture to plant a crop brought a shift in the conception of "opportunity cropping." Instead of this notion applying to the opportunity to double crop after harvesting either a winter or summer crop, opportunity cropping increasingly came to mean planting whatever crop might be profitably grown whenever there seemed to be sufficient planting moisture.

In some cases, the dry years induced farmers to shift to more drought tolerant crops. In the wetter seasons during the 1980s, Peterson planted soybeans and maize, rather than grain sorghum, because of the difficulty of controlling sorghum regrowth. The dry years, however, compelled him to reintroduce sorghum into his cropping system. On the western Downs where cotton could be grown successfully, the better market prices for cotton than grain sorghum persuaded farmers like Ronnfeldt and Newton to make cotton the first crop of choice if there was sufficient moisture. Otherwise, they had to grow the more drought-tolerant sorghum.

Due to the poor cropping conditions in dry years, all of these farmers have expanded cattle operations in their farming system. This has enabled them to use the failed grain crops for forage and grain for cattle. Moreover, Noller began working off the farm to obtain additional income, whereas Peterson expanded contract haying and spraying.

As in the United States, the conservation tillage and cropping innovators in Australia have found that the management of their systems means commitment to a continuously adaptive process. New problems requiring new solutions continually arise.

### *New Farm Landscape and Sociocultural Identity*

As in the United States, these farmers have transformed the landscape and gained a new identity. Over the course of the past three decades,

farm landscapes have changed from relatively small fenced fields with growing crops or fallow cultivation interspersed with pastures and forage crops to more open cultivation. To save soil, sloping areas devoted to crops were modified with contoured water-control structures, and during the 1980s, they were more and more continuously covered with crops or crop residues. Colin Bell put it best when he noted the radical change in his own conception of the appearance of a “good” paddock or field.

Little noticed, farmers have a new identity. They are no longer merely cultivators of the soil growing grain crops. Sensitized to the impact of conventional plow culture, they have embraced conservation cropping as a means of improving the soil and growing better crops. Improvement of their land is a long-term goal of these innovators. As Roy Noller put it, they aim to leave their property to the next generation in better condition in terms of its soil resources than when they got it. This aim is congruent with the English gentry’s value of stewardship, which they have inherited.<sup>28</sup> Farmers are stewards of the land and responsible for its care for future generations (Vanclay and Lawrence 1995). The idea of sustainable agriculture gives new meaning to this widely accepted social value. These innovators, in other words, see themselves as practitioners of a more “natural” way of farming than was practiced with the old plow agriculture, one that enables them to make a living while at the same time protecting and improving the land as a good steward ought to do.

## Notes

1. See chapter 4.
2. Among the reasons listed in a 1976 Queensland DPI report for the slow adoption of stubble mulching practices were the lack of agreement among farmers and “scientific workers” as to its effectiveness, the belief among farmers that surface residue (1) absorbed moisture, thereby allowing less to be absorbed by the soil, (2) increased insect pests and diseases, (3) tied up nitrogen in the soil, (4) and increased the difficulty of mechanical weed control.
3. Lindzey Ward (1995). See also Beckmann et al. 1977.
4. The arguments against burning in the 1960s were based on ideas concerning the importance of organic matter (humus) for “healthy” soils and healthy people, which was popularized in Great Britain and the United States during the 1940s and 1950s (Harwood 1990). In a 1995 interview, Lindzey Ward, who was a young conservation officer in the late 1960s, recalls the perspective and activities of his district manager in Dalby: “Rex Kelsey had a real thing about the retention of stubble. You must not burn it. . . . He had read things about [the importance of] organic matter: the soils were becoming water repellant due to the washing out of the organic matter; plowing was the wrong thing. . . . He

used to run a vendetta every harvest; writing things in the paper about not burning stubble. The organic matter decline threatened the survival of mankind. He really put his heart into it and would really get upset when he saw a stubble fire."

5. Based on Ronnfeldt (1988a, 1988b) and (1995).

6. Common name "diallate." It was developed by Monsanto and commercialized in 1961 as preplant and postplant application for control of wild oats in wheat, barley, and other crops.

7. Mr. Ronnfeldt's personal experience and decision to stop burning occurred at the time that the SCB officers in the Dalby District were writing articles on the importance of retaining stubble to maintain organic matter in the soil. See n. 3 and chapter 5.

8. A blade plow was one of the items of equipment imported by John Deere Australia, Ltd., and turned over to the DPI for testing in November 1969. See chapter 5.

9. In addition to Lindzey Ward, the committee members were Darwin Alexander (grain grower and Chairman), Hector Tod (grain grower), Max Middleton (grain grower), Neville Ronnfeldt (grain grower), and Stan Walsch (agronomist) (Ronnfeldt 1988a; Ward 1988). See chapter 5.

10. See chapter 5 for a detailed description.

11. Mr. Ronnfeldt (1988b) explained how he gained insight into the labor and machinery savings of using herbicide sprays during the Monsanto trials: "In the half hour it took me to go up and back twice, he [Dennis Hayes, Monsanto] had raced over his [trial] area at 25 km/hour, changed rates twice, folded his spray booms, and driven out the gate. As I continued to burn fuel, rubber and use my time for the rest of the day, I compared the rough conditions behind my plough to the fine and moist soil in the wheat stubble in the trial. It was dramatic enough to make anyone stop using a plough."

12. Based on Newton (1988a, 1988b, 1995).

13. For Queensland farmers in the subtropical environment, sorghum regrowth is a problem, because unlike their North American counterparts, they could not depend on frosts to kill sorghum regrowth.

14. The DPI/Monsanto trials conducted on Wayne Newton's farm were part of a program of field trials conducted at various sites on the Darling Downs to inform DPI officers as well as farmers about the advantages of stubble mulching and/or zero-tillage.

15. In the informational vacuum of the early 1980s, the results of these field trials were as informative to DPI officers and to Monsanto as they were to the participating farmers.

16. In 1995, the cost of IPM contractors was \$13/acre/year.

17. Based on Peterson (1988a, 1988b, 1995).

18. See n. 14.

19. See chapter 5 for details of the networking Rod Peterson constructed in developing his conservation cropping system.

20. The planter won Rod Peterson a Queensland Country Life award for best conservation tillage machine (Crothers 1988).

21. Based on Bell (1988, 1995).

22. The brother has a full-time off-farm job but works part-time on the farm and has special responsibilities for maintaining the farm machinery.

23. The group consisted of Colin Bell and his father, Roy Noller and his son-in-law (Ian Moore), Colin Holley, and the two DPI officers (Ken Bullen and Peter Pierce). See chapter 5 for additional details.

24. The use of shear points, instead of planting shears, had been developed by Lindzey Ward (1988). See chapter 5.

25. Based on Noller (1988, 1995).

26. See n. 23 and chapter 5.

27. Based on Heard (1988, 1995).

28. A national survey of Australian farmers (Reeve and Black 1993) found 83 percent "Strongly" or "Mostly" agreeing that "farmers have an obligation to look after the land on behalf of the whole community."

# 8

## The Spread of Conservation Tillage in Kentucky and Queensland

*Coming generations of farmers will find it hard to understand why their forefathers found it necessary to turn, stir, sift and comb every acre of soil every year.*

—S.H. Phillips and H.M. Young, Jr. (1973, 14)

In about 8 years during the 1960s, innovative farmers and farm advisors in Kentucky completed the process of constructing a new culture of cropping agriculture. In Queensland, the developmental process was accomplished in a little over a decade between 1972 when the Soil Conservation Branch began testing and evaluating imported stubble mulching equipment and 1982 when innovative farmers on the western Downs began using herbicides successfully to reduce tillage operations. Some of these innovative farmers began trials of zero- or no-tillage systems not long afterwards. In Queensland as well as in Kentucky, information about these innovative tillage and cropping systems, spurred by media and field officers in the extension and conservation services, created wide interest and excitement in farm circles. Almost immediately, innovative networks of interested farmers began to spring up, engaged in reconstructing the new tillage systems. So rapid did this occur in Kentucky and in Queensland that within a decade the new tillage systems had taken off, creating a new, viable, indigenous culture of tillage and cropping.

In sociological respects, the progressive utilization of conservation tillage techniques by farmers depicts a broad sociocultural movement that changed the normative pattern of farming systems—supporting institutions and networks—and the farm landscape. It comprised a radical change in farmers' attitudes toward the environment, especially their soil resources and plants, and entailed a great increase in knowledge of soil characteristics, methods of seed placement, control of weeds, weather conditions, and use of herbicides (Gersmehl 1978).

In this chapter, we first review data on the spread of conservation tillage systems in Kentucky. (Analysis of the spread of conservation tillage systems throughout the United States is reserved for chapter 9.) In Kentucky, the growth of no-tillage in particular will be seen to have gone through several phases or stages. The initial burst of system construction was followed by a prolonged period of retrenchment and consolidation, before a surge of new interest in no-tillage occurred during the 1990s. In this sense, the growth of no-tillage has been episodic, rather than an s-shaped growth curve typical of most innovative techniques (Rogers 1983). After describing these stages, we examine the major factors that affected the initial takeoff and the subsequent stages of growth in no-tillage as well as in other conservation tillage systems.

Then we analyze the takeoff of conservation tillage in Queensland, Australia. Unfortunately, we do not have data on the present utilization of conservation tillage systems in Queensland. Due to this limitation, we are only able to analyze the initial efforts by institutional authorities to spread conservation cropping systems in Queensland and to review recent changes in policies and institutions impacting conservation tillage and cropping.

### Conservation Tillage Trends in Kentucky

Growth or progress in conservation tillage can be measured in several ways—number of users, acreage, or proportionate utilization. The most extensive information on the use of conservation tillage in the United States has been provided by *No-Till Farmer*. The annual surveys provide information on state and national acreages tilled by various means (e.g., no-tilled, minimum tilled, and conventional tilled). The data permit analysis of the numerical and proportionate growth in the acres under conservation tillage practices but do not provide information on the number of users of different tillage practices.

Using an expansive definition of “no-till” that included various tillage methods that worked 25 percent or less of the surface area, the *No-Till Farmer* reported that 679,000 acres (25.8 percent) of all Kentucky crops were no-tilled in 1972, and an additional 1,354,000 acres (51.4 percent) were minimum (reduced) tilled (table 8.1).<sup>1</sup> (Starting with the 1994 tillage report, ridge-tilled acres were reported separately from other minimum-tilled acreage, which was labeled “Mulch Till” in the report for 1994 and in subsequent years.) The 2,033,000 acres under both conservation tillage systems in 1972 were 77.7 percent of all the cultivated acres in Kentucky.<sup>2</sup> A cultural revolution in cropping agriculture already seemed well underway, even though as will be shown in chapter 9, the

Table 8.1. Trends in Tillage Systems in Kentucky: 1972–1998 (Million).

Year	No-Till*		Ridge Till†		Mulch Till‡		Conventional		Total	
	Acres	(%)	Acres	(%)	Acres	(%)	Acres	(%)	No.	(%)
1972	679	(25.8)	—	—	1,354	(51.4)	603	(22.3)	2,636	(100)
1973	838	(28.6)	—	—	1,552	(53.0)	539	(18.4)	2,929	(100)
1974	1,103	(33.3)	—	—	1,614	(48.7)	597	(18.0)	3,314	(100)
1975	1,063	(31.8)	—	—	1,690	(50.4)	595	(17.8)	3,348	(100)
1976	1,040	(27.7)	—	—	1,842	(49.1)	871	(23.2)	3,753	(100)
1977	989	(25.9)	—	—	1,943	(50.9)	885	(23.2)	3,817	(100)
1978	972	(24.5)	—	—	1,978	(49.9)	1,014	(25.6)	3,964	(100)
1979	993	(26.0)	—	—	1,943	(50.9)	885	(23.1)	3,821	(100)
1980	935	(18.6)	—	—	2,349	(46.8)	1,737	(34.6)	5,021	(100)
1981	1,170	(25.3)	—	—	1,021	(22.1)	2,437	(52.6)	4,628	(100)
1982	1,476	(33.9)	—	—	1,387	(31.9)	1,485	(34.2)	4,348	(100)
1983	1,024	(28.7)	—	—	1,195	(33.5)	1,348	(37.8)	3,567	(100)
1984	1,104	(21.1)	—	—	1,574	(30.1)	2,546	(48.8)	5,224	(100)
1985	1,320	(25.2)	—	—	1,536	(29.3)	2,382	(45.5)	5,238	(100)
1986	800	(21.6)	—	—	1,463	(36.0)	1,725	(42.4)	4,068	(100)
1987	802	(22.4)	—	—	1,276	(35.6)	1,508	(42.0)	3,586	(100)
1988	780	(22.5)	—	—	1,345	(38.8)	1,339	(38.7)	3,464	(100)
1989	915	(24.8)	—	—	1,251	(33.9)	1,521	(41.3)	3,687	(100)
1990	1,069	(28.7)	—	—	983	(26.4)	1,669	(44.9)	3,721	(100)
1991	1,158	(30.9)	—	—	1,032	(27.5)	1,563	(41.6)	3,753	(100)
1992	1,273	(33.9)	—	—	1,047	(27.9)	1,434	(38.2)	3,754	(100)
1993	1,541	(40.0)	—	—	1,028	(26.7)	1,284	(33.3)	3,853	(100)
1994	1,640	(44.3)	1	(0.0)	830	(22.5)	1,229	(33.2)	3,701	(100)
1995	1,742	(47.5)	2	(0.1)	784	(21.4)	1,141	(31.0)	3,669	(100)
1996	1,861	(49.3)	2	(0.1)	903	(23.9)	1,007	(26.7)	3,773	(100)
1997	1,816	(48.3)	2	(0.1)	824	(21.9)	1,117	(29.7)	3,759	(100)
1998	1,834	(47.6)	1	(0.0)	886	(23.0)	1,132	(29.4)	3,853	(100)

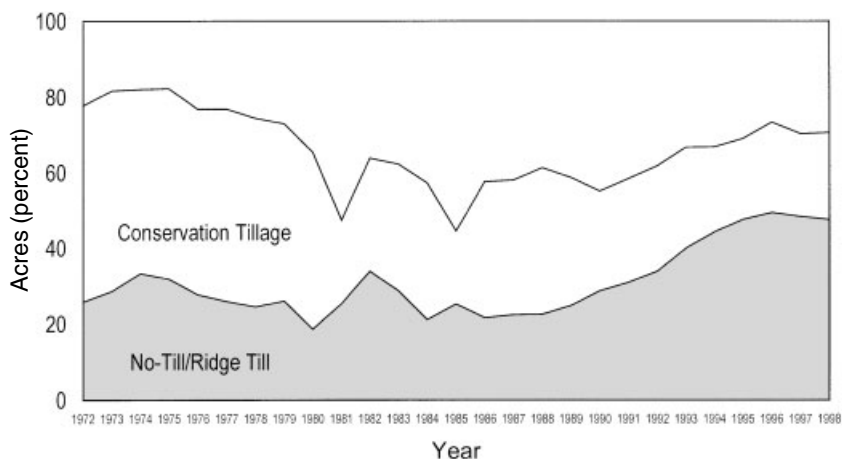
Source: From *No-Till Farmer* for years 1972–1977; for 1998, from CTC 1998 Survey Report.

\*For 1972–1982, up to 25 percent of surface area could be worked. Includes no-till, till-plant, chisel plant, rotary skip fill, etc. For 1984–1998, “no-till” is defined as planting in a narrow unprepared seedbed usually 1–3 inches wide.

†For 1993–1998, ridge-till is recorded separate from minimum or mulch tillage.

‡Limited tillage over the entire surface. 1984 and subsequent years, any system other than no-till that retains 30 percent residue cover. For 1994 and following years, this is designated as “Mulch Till.”

Figure 8.1. Trends in tillage systems in Kentucky: 1972–1998.



early 1970s was midway in the *takeoff* period, or the early expansion of no-tillage nationally. The trend data indicate, moreover, that satisfaction and utilization of both methods of conservation tillage waxed and waned during subsequent years (fig. 8.1). In 1974, no-till acreage reached a temporary plateau of more than a million acres. Together with about one-half of the cropland minimum tilled, nearly four out of every five acres of cropland in Kentucky were under conservation tillage systems. There was little change in either the total or proportionate acreage under conservation tillage in 1975, but thereafter no-till acreage began to decline both numerically and proportionately. This marked the end of the takeoff period of rapid increase in no-tillage in Kentucky.

From this early peak, conservation tillage systems, both no-tillage and minimum tillage, progressively lost favor with Kentucky farmers. After 1975 both the number and percentage of cropland acreage conventionally tilled began to rise. To some extent, this was due to the rise in total cropland acreage—acres withdrawn from soil bank and returned to production—that was tilled conventionally. This period of *retrenchment and consolidation* lasted through 1980. At this point, only 935,000 acres (18.6 percent) of cropland was no-tilled, a 15 percent decline from the 1974 peak.

However, cropland acreage, which had been expanding steadily since 1972, jumped dramatically in 1980 and remained at a relatively high level for several years. Total cropland rose from 3.8 million acres in 1979 to 5.0 million acres in 1980, an increase of nearly one-fourth in one year.



The total acreage of crops grown in Kentucky remained above 1979 levels until 1987 when it fell to 3.6 million acres, at which level it has tended to remain.

The big increase in total tilled acres in the first part of the 1980s tended to mask a general rise in no-tillage to over a million acres, which occurred during the first half of the 1980s. But, the expansion in no-till acreage in the first half of the decade was reversed for the remainder of the decade when no-till acreage dropped to the level of late 1970s. Although nationally the 1980s was a period of slow expansion in conservation tillage,<sup>3</sup> the advance and retreat pattern in Kentucky indicates that the 1980s continued the *consolidation* stage in the growth of conservation tillage and cropping.

During this decade, Kentucky's farmers no-tilled about one-fourth of their cropland and had about 55 percent of cropland under some form of conservation tillage. Although the proportionate use of various conservation tillage methods was relatively lower during this period than in the early 1970s, it was almost twice the national level at this time, and the relative extent of no-tillage in Kentucky was five times the national level.

But, during the 1990s Kentucky farmers joined the *rapid expansion* of no-till cropping, which has been a national phenomenon.<sup>4</sup> Despite a small decline in the percentage of the acreage no-tilled in 1998, the 48 percent no-tilled is almost twice the proportion in 1989. With an additional 23 percent of the cropland minimum tilled, Kentucky farmers raised 71 percent of their crops under conservation tillage systems in 1998. (Maryland ranked with Kentucky as national co-leaders in the proportion of cropland no-tilled in 1998.)

### Spreading the Seeds of No-Till Systems in Kentucky

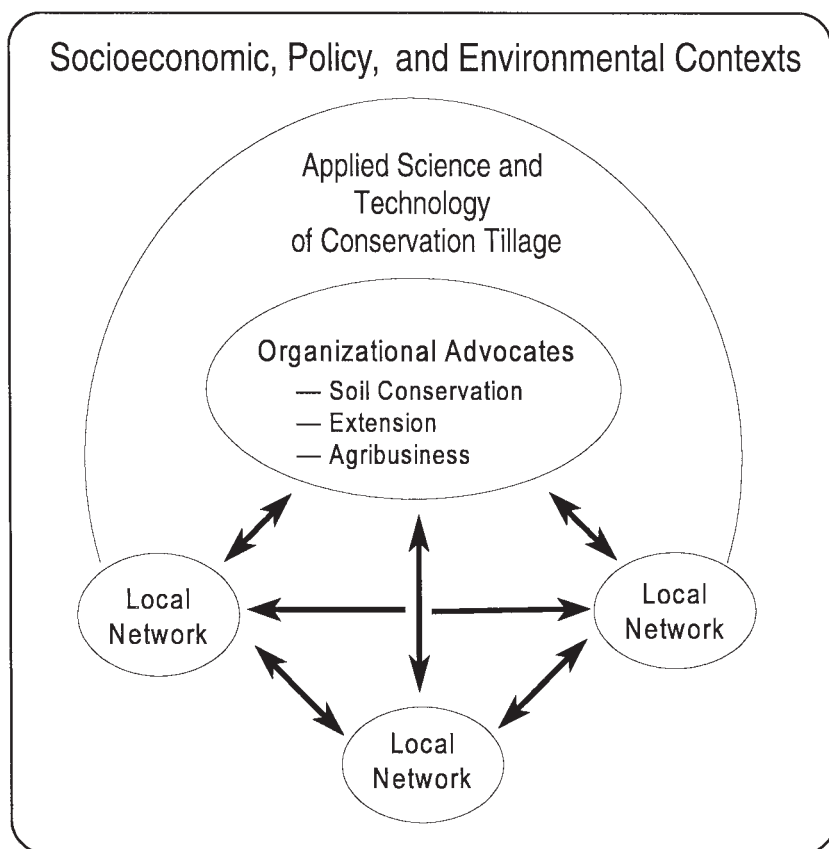
Although the foregoing data are in acres tilled, rather than the number of adopting farmers, it seems evident that the advance of no-tillage over the past three decades in Kentucky did not conform to the familiar logistic, diffusion curve, which earlier studies of the trial use of new tillage practices have found (Choi 1981; van Es et al. 1986; Korsching et al. 1983). As reflected in our acreage data, the pattern of actual utilization has been episodic. The initial takeoff of no-tillage systems in Kentucky was followed by a period of consolidation or retrenchment. It is apparent that some farmers had difficulties; some cut back on the use of their new systems, and others, perhaps, reverted to conventional tillage. Although no-tillage rebounded in the early 1980s, the acreage no-tilled dropped thereafter to the late 1970s level until 1990. The proportion of cropland no-tilled was also the lowest ever recorded. Thus, there was a

prolonged period of retrenchment and/or consolidation, although, as we will see in chapter 9, at a relatively high level of no-till usage compared to other states. Most recently, there has been a period of *rapid expansion* to the highest level ever of no-till usage. These phases in the spread of no-tillage raise questions about the factors and processes that explain this episodic pattern of growth.

Farmers' "utilization" of conservation practices generally has been recognized by analysts as a process affected by many factors—social, economic, ecological, farm, and personal (e.g., Halcrow et al. 1982; Nowak 1984; Lovejoy and Napier 1986; van Es 1984). Although previous sociological studies invariably have treated no-tillage or mulch tillage as if they were single items of technology and their adoption as an individual issue, we have emphasized the importance of considering these as complex systems and the innovative-adoption process as occurring in and through the agency of local networks of farmers and technical advisors. The local network performs four critically important functions in the innovation of conservation tillage systems. First, it supports and sustains individual innovators during the period—often several years—they are engaged in "experimental learning" and constructing a tillage system, which they can operate satisfactorily. Second, it connects the local system with a global resource-support network. Third, through the innovations of farmer members, the network confirms the legitimacy of the central beliefs and operating principles of the new tillage systems. Finally, the network is identified as the bearer or repository of the new "indigenous" farming culture. In this sense, the construction of innovative tillage/cropping systems, such as no-tillage, are network products. It follows that the key mechanism in the innovation-diffusion of any complex system, such as no-tillage, is the establishment of innovative networks. The conceptual model of the factors affecting innovative networks in the innovation-diffusion of conservation (tillage) cropping systems is presented in figure 8.2.<sup>5</sup>

By the late 1960s, a new culture of conservation cropping can be said to have become established in Christian County in the sense that many farmers had become committed to no-tillage production of corn and soybeans and minimum-tilled wheat. It entailed new machines, techniques of weed control, crop rotations, and new attitudes and beliefs about soils, plants, and their management. Here, we examine the factors—policies, institutional, and environmental—that affected the spread of innovative tillage systems beyond the initial networks of farmers in Christian County. Then we discuss the institutional factors involved in spreading innovative networks in Queensland.

Figure 8.2. Multiplying local networks of conservation tillage practitioners.  
 Source: Adapted from Constant (1987).



### *Prior Research on the Adoption of No-Tillage*

In his review of prior sociological studies of the adoption of soil and water conservation practices, Nowak (1984, 224) comments that "sociologists have ignored a basic geographic principal [sic] . . . [that] technologies diffuse across geographic areas." The geographical spread of innovations from one farmer to another "is helped along" observes Nowak "by [the latter] being able to see the results of . . . [the farmer's] adoption, being able to talk to a neighbor who has experimented with the technology, and to . . . local purveyors of technical assistance . . . [if they] have had previous experience with this

technology.” Although citing several studies that examined the relationship between individual innovativeness and participation in various types of networks, Nowak was not able to cite studies that specifically analyzed the role of network or institutional factors in innovation per se. The discussion of diffusion of conservation tillage systems in this chapter carries Nowak’s conceptual perspective a couple of steps further. As already pointed out, we argue first that system innovation (e.g., tillage systems) is inherently a network event, and second, that in the “diffusion,” or spread, of no-till cropping from the original sources—the Christian County innovators—to spatially distant farmers who constructed innovative no-till systems, the agency of institutional and/or company representatives is critical. Finally, because of the differences in soils, weather patterns, weed, and pest regimes, the diffusion process usually constitutes a reinvention of the tillage system.

Despite the lack of explicit analysis of innovative networks in his 1977 study of no-tillage in Christian County, Choi (1981, 63) comments that Reeves Davie, the county extension agent, “had played a significant role . . . [in introducing no-tillage] by organizing group tours to inspect no-till fields.” On the other hand, the local soil conservation agent was less than certain that no-tilling sloping fields was desirable, or that he should offer advice on tillage practices: “These days, many farmers are doing more crop production than they should. . . . I see many farmers who are in the crop business when they should be doing cattle business because of their sloping land. . . . Sometimes I tell them to try no-till although it is not my job to tell farmers how to farm” (Choi 1981, 64). Choi found that frequent contact with either institutional agent was a significant predictor of having tried no-till. Indeed, most of the farmers who had tried no-till had talked with both agents, but Choi did not examine their respective roles in the diffusion process. Studies of no-tillage innovation in Illinois (van Es et al. 1986), Washington (Carlson and Dillman 1986), and Iowa (Bultena et al. 1983; Korsching and Hoban 1990), which are discussed more fully in chapter 9, amplify the importance of institutional agencies in spreading the innovation but do not analyze the underlying process.

## The Takeoff Period

### *Expanding Innovative Networks in Kentucky*

The Kentucky Cooperative Extension Service, as represented by certain key specialists and interested county agricultural agents, was the primary agency in the initial phase of diffusion. The main goals of Extension Specialists were to identify Extension Agents who would identify

prospective innovators and work with them in experimenting with the new tillage systems. The principal instruments used by extension in accomplishing these goals were the establishment of *farmer-scientist trials* and the holding of *field days*. Supported by local county agricultural agents, these events invariably led to the establishment of new innovative networks of local farmers, which the specialists and extension agents and knowledgeable professional workers, assisted in the developing the local knowledge of no-tillage cropping.

The Cooperative Extension Service in the person of Shirley Phillips and several other Extension Specialists and cooperating County Extension Agents, who became early converts to no-tillage, provided the principal institutional basis for spawning new innovative networks of extension agents and farmers over the state. No-tillage appealed to Phillips (1992) because the cultivated fields on Kentucky's rolling hills were subject to severe erosion, which no-tillage minimized, and because he was persuaded by advocates of an organic agriculture that plowing was unnecessary to successful cropping.

Earlier it was pointed out that, before taking up farming, Harry Young, Jr., had worked as an Extension Specialist, and as a farmer he had continued working with Reeves Davie (Christian County Agricultural Agent) and Shirley Phillips (Crops Specialist). Thus, the three were bound in a web of institutional and friendly relationships when Harry Young began to experiment with a no-tillage system.

In expanding interest in no-tillage locally and in setting the stage for institutional and media networks to spread information about no-tillage through other networks, Reeves Davie played a key role. He had many formal and informal network linkages, and his enthusiasm for no-tillage was infectious. Within Christian County, when the Extension Board recommended holding a field day, Reeves accepted the responsibility for implementing the plan. Implementation invariably involved farmer meetings with appropriate extension specialists. Publicity about farmer programs and planned field days was generated by the County Extension Office. In addition, Reeves Davie worked closely with the instructors of Vocational Agriculture Adult Farmer classes. During the 1960s, two courses for farmers were held each fall and each spring, and Reeves Davie was regularly invited to teach one class on no-tillage in each course. This became one of the most important vehicles for spreading information and stimulating interest in field days on no-tillage locally. The normal multitude of requests for advisory assistance from individual farmers was also a routine vehicle for spreading information.

The organization of extension operations on an area basis also facilitated no-tillage networking, especially in the Pennyrite Extension Area,

which included Christian County. Although extension programming on an area basis had been carried out for some time, in 1964 the Kentucky Cooperative Extension Service (Seay 1964) began to designate individual agricultural agents as subject matter specialists (e.g., hogs, beef cattle, forage crops, and the like) for the multicounty area. This increased agent contact with farmers within an extension area. Reeves Davie was appointed as the Farm Management Specialist for the Pennyryle Extension Area, and his meetings with farmers in other counties facilitated spreading information about special events in Christian County as well as about the management benefits of no-tillage. Publicity through state and extension channels in these ways made a no-till field day in Christian County a state event.

Within the extension system, Shirley Phillips had a twofold job responsibility. On one side, he was responsible for collaborating with Experiment Station researchers in establishing varietal evaluation trials in key localities over the state. In this aspect of his role, Shirley had to locate cooperating farmers and work with them in setting up the varietal trials and in collecting the performance (yield) data. On the other side, Shirley Phillips was the official crops production “expert” of the Extension Service. In this capacity, his annual plan of work was largely determined by the requests of farmers, forwarded by their County Extension Agents, for educational programs dealing with various issues in the production of commercial field crops (e.g., corn, soybeans, sorghum, wheat, and the like). Soil erosion was a major problem of crop production in Kentucky, and Shirley had published recommended tillage methods for corn production (Phillips and Loeffel 1963). At the time, however, he did not recommend no-tillage production.

In the course of his ordinary activities, Shirley Phillips had contact with County Agricultural Agents over the state of Kentucky. News of forthcoming events, such as field days, was easily spread through normal Extension Service channels. Something as notable as a field day in Christian County with a tour of on-farm no-till corn and/or soybean trials was certain to interest agricultural extension agents and farmers in other counties.

Field days featuring on-farm trials, teams of extension specialists, and often notable outside experts became the paramount vehicle for cementing farmer interest in no-tillage and initiating requests for on-farm trials and innovative networks in other counties. The no-till field days in Christian County set a pattern that was followed, although less elaborately, in other counties and districts. The important activities associated with the field days in 1966, 1967, and 1968 began the night before with a gathering of professional workers—agricultural scientists, exten-

sion agents, and specialists—at a local hotel for dinner and after-dinner discussion of recent research and on-farm trial experiences. As Reeves Davie (1966) put it: “We’d have supper; usually 25 or 30 were there. They would be asking, ‘what’s going on with no-till?’ So, we would put Shirley Phillips in the middle. . . . He had the information from the University of Kentucky [research] as well as from us [Christian County] and from Pulaski County.<sup>6</sup> He had a good background for . . . [reporting and evaluating results], and he did a real good job.” Professional workers from Kentucky and other states thus gained particularly useful information about no-tillage.

In the morning of the following day, people attending the field day registered and assembled in the auditorium of the local community college for presentations by invited speakers. After lunch, they boarded busses to visit farms in the county where they viewed the comparative performance of conventional and no-till crops—different varieties and herbicide applications—the equipment used, and listened to Harry Young and specialists of the no-tillage extension team discuss results of the field trials.

The field days attracted wide interest and were the basis for establishing innovative networks in other counties. The first of the widely publicized field days occurred in 1966. It was attended by 325 persons from nineteen counties (Davie 1996). Field days in the following years were even larger—726 people from eighteen states registered (perhaps 100 more did not register) for the 1967 field day, and nearly a thousand came in 1968. To agricultural scientists from other states who had struggled to attract the interest of farmers in their own areas in no-tillage, the attendance was amazing, even overwhelming (Davie 1996).

Kentucky farmers’ interest in no-tillage evidenced in the 1965 and 1966 field days prompted Extension Service administrators to expand applied research on no-till problems and to establish a team of no-till extension workers. In addition to their applied research, the no-till team worked with county agricultural agents throughout the state in establishing no-till trials and in advising agents and farmers on no-tillage practices. The team initially consisted of extension specialists in crops (Shirley Phillips), soil fertility (Harold Miller), weeds (James Herron), and agricultural engineering (Robert McClure). Applied research findings were publicized through the popular media, especially the farm papers (e.g., *The Progressive Farmer*) and field days.

As a result of the big field days, a “nucleus of 3 to 5 farmers per county who became excited [about no-till] was formed, and did more, I believe, in selling other farmers about no-till than did the professional extension workers or scientists” (Phillips 1992). To capitalize on this expanding

interest, the Kentucky Extension Service leased four Allis-Chalmers no-till planters and in turn loaned them to county agricultural agents to establish demonstration trials (Phillips 1992). Chemical and machinery companies quickly recognized the importance, as a market development strategy, of providing a planter for local farmers to borrow on a trial basis. A number of counties acquired demonstration planters in this way.

Many professional workers, of necessity, learned about no-tilling at extension meetings and the field days along with the visiting farmers. But, under the extension area system in operation from 1966 to 1969, one county extension agent in each eight- or nine-county area was the designated agronomy specialist. When the State Extension Service certified no-tillage as an acceptable cropping system in 1966–67, the state specialist team and the extension area agronomy specialists became the leaders in the program to spread the practice of no-tillage. The area agronomy agents shouldered much of the responsibility for no-till demonstration work in their multicounty area. Some had trials in nearly all the area counties—pulling the no-till planter from one trial site to another.<sup>7</sup> Others established demonstration trials in the home county. Field days and educational programs featuring state and area specialists with data and colored slides were the vehicles for spreading information about no-tillage problems and possible solutions to farmers.

For their part, the team of state extension specialists was as much interested as were farmers in testing and adapting the system in different areas of the state. The state no-till team, which Shirley Phillips headed, established a standard format for the demonstration trial with “conventionally tilled [crops] on all sides of the no-tilled [crop], so that if we had failures or successes we had a comparison that farmers could see and feel. . . . Over a three year period, we had these side by side comparisons in 85 of the 120 [Kentucky] counties” (Phillips 1992).<sup>8</sup>

By these means, local networks of innovative farmers were quickly established in most Kentucky counties. For nearly every one of the early no-till innovators, which we have chronicled, participation in a field day at the Young (and other) farms in Christian County was a key factor in their decision to reinvent a new no-tillage system on their farm. In neighboring Hopkins County, Tom Porter first saw no-till corn at Dawson Springs in 1961, but the decision to purchase a no-till planter and begin developing a no-till system in 1967 came after observing no-till crops at the Young farm in the interim. Participation in the 1967 field day in Christian County played an important part in John Barnett’s (Henry County) and Earl Welborn’s (Todd County) decisions to experiment with no-till cropping.<sup>9</sup> As a University of Kentucky student, Mike Ellis had visited the Young farm in Christian County. Davis and Kirk Dix-



son's (Hickman County) decision to construct a no-tillage production system in 1971 came after having observed no-till trials on nearby farms. They, in turn, became local no-till demonstrators.

### *Forces*

Farmers in Kentucky were attracted to no-tillage by the relative benefits of the new system. Heading this list of benefits are "more net income from lower operating costs and higher volume, and conservation of soil and water" (Young 1972, 1). Several of the Kentucky no-till innovators reported that analysis of their farm management records demonstrated that land used for crops returned substantially higher income than land used for pasture and livestock. This income advantage of no-till cropping was partly a function of policy and market forces. Commodity grain reserve and price supports helped reduce risks of grain growing and sustain its profitability. From the mid-1960s through 1973, moreover, prices of corn, soybeans, and wheat rose almost continually. Meanwhile, through most of this period the trend of costs for fertilizer lagged below that for machinery and fuel.<sup>10</sup> Even so, farm costs generally were rising as rapidly as prices. Rising grain prices and continual cost-price pressure provided strong incentives to expand production through increasing efficiency. One means of increasing efficiency was to use the same machinery to grow crops on land that had been in the Soil Bank. Farmers in Kentucky also found that by no-tilling soybeans they could grow three crops in 2 years, thereby increasing productivity substantially.

In Kentucky, the pattern of land use during the takeoff period, which ended in 1975, reflects these forces. Between 1972 and 1975, total cropland acreage grew from 2.6 to 3.3 million acres (i.e., by 27 percent). (See table 8.1.) At the same time, the acreage no-tilled increased 57 percent (384,000 acres) and the acreage minimum tilled grew by 25 percent (336,000 acres). Growth in the practice of both conservation tillage systems more than equaled in acreage terms the increase in total cropland. During the takeoff period, therefore, Kentucky farmers slightly increased the level of conservation protection through conservation tillage of cropland while substantially increasing the total cropland acreage (see fig. 8.1).

For most Christian County, Kentucky farmers who by 1977 had gained some experience with no-tillage, the labor- (and time-) saving aspect was the single most important advantage of no-till (Choi 1981). They considered erosion control and double cropping as the next most important advantages of no-tillage. In the prevailing economic situation, these advantages of no-tillage gradually led Christian County farmers who no-tilled to become more specialized in grain growing. In 1977, the

proportion of adopters for whom cereals and feed grains—corn, soybeans, wheat—were their principal crops had nearly doubled (i.e., they had stopped raising tobacco).

The advantages of no-tillage also led farmers to develop new cropping systems and to expand farming operations. The development of double cropping is illustrated by actions undertaken by several of the innovators (chapter 6). Through double cropping, John Barnett increased the land efficiency of his farming operations by 30 percent. The rising prices for soybeans made this a popular option. In 1965 (before no-tillage), Christian County farmers grew 2,100 acres of soybeans and earned \$150,000. In 1974, 7 years after Harry Young successfully double cropped soybeans, Christian County farmers raised 71,000 acres of soybeans and earned \$12 million. (Davie 1996).

But, the greater speed in planting also meant that more acres could be planted, and farmers who desired to do so could expand their farming operations. During the first 5 years of using no-tillage, Christian County farmers increased the acreage farmed on average by 50 percent.<sup>11</sup> Adoption of no-till systems thus enabled farmers either to expand their farming operations or reduce labor inputs or both.

### Consolidation and Retrenchment

The decline in no-till acreage in Kentucky, which began in 1974, extended through 1980. The recovery during the first half of the 1980s was followed by another period of reduced no-till acreage. Although the appeal of no-tillage wavered during this 15-year period from 1974 to 1989, most Kentucky farmers who had shifted from conventional to conservation tillage systems maintained this commitment. This is apparent in that usually when no-till acreage declined (see table 8.1), the acreage mulch (or minimum) tilled increased. On the whole, the darkest period for conservation tillage was from 1984 to 1989 when only about 2.1 million acres, less than 60 percent, of cropland was under conservation tillage.

Clearly, Kentucky farmers were having difficulties in sustaining their commitments to no-tillage. In 1977, Choi (1981) found that about one-third of the Christian County farmers who had ever tried no-tillage had reduced their no-till acreage, and nearly 28 percent had abandoned it and did not plan to return to it. Some of these farmers had shifted to minimum tillage, and others alternated between no-till and conventional tillage when they felt it was necessary.

The difficulties encountered by Kentucky farmers in sustaining no-tillage systems are not exceptional. All the innovators chronicled in

chapter 6 had difficulties in obtaining satisfactory long-term chemical weed control and in managing the associated risks. Several encountered a buildup of rodents in fields when there was substantial crop residue, and there were crop establishment problems in poorly drained fields.

Christian County farmers who had stopped no-tilling in 1977 stated the problem to Choi (1981, 79) in this way:

“With no-till, you take a chance altogether on spray to do the job.”

“Since weather affects chemicals’ effectiveness, no-till is a more ‘chancy’ thing.”

“To have good no-till crops every year, you’ve got to be a good student of the no-tillage method, and I am not.”

Choi (1981, 79) went on to point out that “almost all farmers were aware of the fact that there are fewer possibilities to correct errors with no-till than in conventional tillage systems, and of the fact that continuous no-till crop production may lead to certain problems such as weed and insect infestation.” The loss of options amounts to greater risk of crop loss and/or increased costs. The possibility of increased weed and insect problems was a real experience of most farmers, which required new adaptive technology or partial reversion to conventional tillage, a strategy that many in fact pursued.<sup>12</sup> Management of these difficulties not only required time and effort in acquiring new knowledge and skills but also often additional out-of-pocket costs.

Confronted by these difficulties in attempting to use no-tillage, it is not surprising that some farmers stopped no-tilling and that others decided to use either minimum or conventional tillage to control weed, disease, and rodent problems, deferring the use of no-tillage to a time when conditions were more favorable. Such experiences of innovators, which slowed their use of no-till cropping, also doubtless increased the reluctance of farmers who had not tried no-till cropping to attempt construction of their own systems.<sup>13</sup>

Although there was some retrenchment in no-till, and occasionally in minimum till acreage, part of the decline in the *proportion* of cropland under conservation tillage systems during the decade from 1974 to 1985 was due to a big increase in total cropland. Farmers decided to till conventionally land that had been in grass that they brought into crop production. This resulted from changes in the market and policy forces impacting farmers.

### *Markets and Policies*

Spurred by favorable price-cost relationships, Kentucky farmers continued the expansion of cropland, which had started in the 1960s, through

1980.<sup>14</sup> Farmers also increased farm inputs, especially chemical inputs. Prices of farm inputs rose accordingly. This weakened the cost-benefit of no-tillage. For farmers experiencing difficulties with no-tillage or who thought of it as a risky practice, the decline in the cost-benefits reduced the incentives to innovation. For these farmers, the safest choice in expanding production was to cultivate larger acreages conventionally.

As the 1980s unfolded, the market situation changed dramatically. Confounding the economic experts, the export market for U.S. grain weakened due to a worldwide recession and a strong U.S. currency, which made American grain relatively more expensive. The declining profit margins pressured farmers to expand production to sustain farm incomes. Because of the cost-price squeeze and no-till's cost-saving aspects, interest in no-tillage accordingly increased. The rise in the acres no-tilled between 1981 and 1985 reflects this cost-saving interest.

Meanwhile, the principal governmental policies governing the operation of the Soil Conservation Service (SCS), Agricultural Conservation Program (ACP), and other soil conservation agencies, which had remained in place and encouraged production-oriented tillage practices during the 1970s, began to change (Batie 1982). The Soil and Water Resources Conservation Act of 1977 and subsequent legislation began to erode subsidies for production-increasing but soil-wasting practices. The PIK (payment-in-kind) program of the first Reagan administration also weakened the connection between production and support payments. But, the impact of these policies was relatively weak compared to the market price incentives to maintain or even expand production.

The Food Security Act of 1985 changed the policy outlook for farmers in several ways. To support grain grower incomes, the PIK program was replaced by a policy of specified target prices for key commodities and deficiency payments. To reduce grain production, protect erosion-prone land, and provide wildlife habitat, while sustaining farm income, the 1985 Food Security Act established the Conservation Reserve Program (CRP). This enabled farmers to receive rent from the USDA for erodible cropland placed under a 10-year reserve contract. The program was quite effective, as indicated by the reduction in over 1.5 million acres of cropland in Kentucky between 1985 and 1987.<sup>15</sup> It is apparent that up to one-half million of these highly erodible acres transferred to the reserve program was land that had been no-tilled, and this transfer and a more restrictive definition of no-till are the most important factors in the reduction of no-till acreage during the latter half of the 1980s.

### *Expanding Research and Technology*

An important factor in the continued commitment of Kentucky farmers to no-tillage during this period of rapid change in economic fortunes

and policy change was increased understanding of the science of no-till cropping. At the beginning of the period of *retrenchment* in 1975, there were many unsolved problems. As Shirley Phillips (1992) would later recall: "We knew [in the mid-1960s] that no-tillage worked, but we didn't know why it worked." This realization, plus the successes of innovative farmers, stimulated research administrators to expand research on the problems encountered. The new focus was coincidentally associated with the promotion of Shirley Phillips to the position of Assistant Extension Director for Agriculture. In his new administrative position, Shirley Phillips had easy access to key research faculty, and he was able to build interest in studying problems of no-tillage. Shirley recognized knowledge gaps in no-tillage production, and as two colleagues put it, "his type of leadership . . . made it a pleasure rather than a chore to work with him" (Thomas and Blevins 1996, 5).

"The [research] team was organized informally; it *never* had an overall project nor a budget" (Thomas and Blevins 1996, 5). There was never any official administrative direction, nor was there ever any constraint. Instead, with Phillips' encouragement, the agricultural scientists developed an interest in studying the fundamental questions of soil structure, soil chemistry, water infiltration, and the like, which no-tillage raised. They seized the opportunity to become engaged in the process of knowledge creation.

In 1970, the Kentucky Experiment Station held the first of several conferences (field days) featuring no-tillage research. There were varietal, herbicide, and fertilizer application trials, different cover crops, multi-cropping trials, and the like. The event was a huge success. "Three or four thousand farmers from not only Kentucky, but also . . . throughout the Midwest" attended (Phillips 1992). An important consequence of the research conferences and seminars was the strengthening of relationships among scientists and professional workers interested in conservation tillage problems. Strengthening of the advisory systems through increased understanding, coupled with continual improvements in machinery and chemical herbicides, helped innovators overcome practical problems with their new systems and helped sustain conservation tillage systems during the 1980s.

### The Rapid Expansion

Between 1990 and 1998, cropland in Kentucky managed under no-tillage and ridge-tillage systems doubled, both in acreage and as a proportion of the total cropland. Even with use of the more restrictive definition of "no-tillage"—a narrow seedbed 1 to 3 inches wide—the acreage no-tilled in 1998 was two-thirds larger than the highest year—

1974—during the takeoff period. Meanwhile, even though a smaller acreage was mulch tilled, the overall practice of conservation tillage was more widespread in Kentucky than ever before.

The rapid expansion in Kentucky was influenced by factors that similarly impacted farmers' tillage practices nationwide, including the continued expansion in research and technology and growing environmental consciousness. However, the impact of changes in the policy environment has been the most important. As a leading Kentucky soil scientist put it, "I attribute most of this expansion [since 1990] to conservation compliance. Improvements in weed control and planting technology have had some impact, and also changes in farmers' acceptance of no-till. . . . But, the biggest change is obeying the law: conservation compliance. If a person had an attitude problem, he either adjusted or he lost his money, and his attitude could be adjusted with money. . . . [For example,] Hickman County, Kentucky, a county that, just a few years ago, looked like it would wash away because everybody refused to no-till. Now, they have 80 percent of their corn and about 100 percent of their double-crop soybeans no-till" (Murdock 1995).

### Expanding Conservation Tillage Networks in Queensland, Australia

By 1981, a number of farmers on the Downs had chisel plows (64 percent), scarifiers (87 percent) and/or tined cultivators (47 percent), but only a minority had obtained a scariseeder (7 percent) or trash combine (8 percent) (Chamala et al. 1983). Although only a small minority of farmers on the Downs were still burning stubble, except to double crop, a disc or moldboard plow remained the predominant implement of first cultivation, which left little stubble to protect fields during the fallow period. It was evident to SCB administrators at the time that, although a few innovative farmers on the Downs were quite advanced in their stubble mulching methods, most farmers were not following the innovators, and in this respect, an indigenous culture of conservation tillage had not been established.

Several factors were important in the slow advance of stubble mulching systems. On the one hand, because of the preoccupation of SCB administrators and most field officers with the planning and construction of contour banks, waterways, and drainage ditches, under the declaration of the Area of Erosion Hazard, agronomic measures of erosion control were easily ignored. This limited SCB view of solutions to erosion problems was compounded by the lack of agronomic training of SCB officers. With training and competency mainly in the engineering

of water control measures, SCB officers tended to be quite reluctant to address agronomic techniques with farmers (Begbie 1988). On the other hand, agronomic measures of erosion control were primarily the concern of the Agriculture Branch of the DPI rather than the SCB officers. For a similar reason, Agriculture Branch officers tended to avoid soil erosion issues as outside their domain of responsibility, and even knowing that erosion was slowed by a stubble mulch, they had little incentive to gain competence in this kind of erosion control.

Up to 1982, Agriculture Branch field officers operated primarily as observers of SCB efforts to save soil through construction of engineering works. Although a few of the Agriculture Branch officers had been involved with machinery evaluation committees, this program was marginal to their main interest in helping farmers improve the profitability of their cropping systems. Neither Agriculture Branch officers nor administrators felt that the favorable soil-conserving results of the machinery evaluation program necessarily justified their involvement in promoting stubble mulching. Like farmer clients, they questioned the profitability of stubble mulching. Even when Agricultural Branch officers addressed erosion problems, as in the central Highlands, they accepted standard structural measures as the principal means of erosion control (Childs 1988). Consequently, no one in either branch had clear responsibility for, or much competence in, methods of stubble mulching.

The institutional focus on structural measures and the avoidance of the complementary method of stubble mulching in controlling soil erosion was reflected in the attitudes of most farmers on the Downs. Although more than 50 percent of the farmers on the Downs recognized that they had a "serious" or "very serious" erosion problem, most either had not developed an action plan to deal with the problem (46 percent) or were considering only contour banks (37 percent) (Chamala et al. 1983).

The reluctance of farmers to seriously consider stubble mulching methods was not entirely due to ignorance. Most farmers recognized that soil and moisture saving were advantages of stubble mulching. But, many farmers also associated a wide range of disadvantages with stubble mulching, including harboring disease, insect buildup, nitrogen tie up, clogging of machines, requiring machinery modification, and the like (Chamala et al. 1983). Although admitting that stubble mulching could be a "profitable" practice (77 percent), the lack of a serious personal consideration of the practice is reflected in the fact that 80 percent felt they were already using the best conservation practices they knew of. Clearly, the farmers did not believe that they would gain substantial net benefits from stubble mulching.



Administrative recognition of the continuing problem of erosion and the lack of clear responsibility for promoting stubble mulching led the Agriculture Branch and SCB in 1981 to develop a coordinated Conservation Cropping Extension Program for the Darling Downs region. It was one of the first steps made by the Agriculture Branch to become involved in promoting stubble mulching.<sup>16</sup> However, disagreements over priorities and respective responsibilities handicapped the effort.

The 1982 study of farmers' fallow management practices on the Downs (Chamala et al. 1983) helped administrators of both branches to identify informational gaps of both field officers and farmers to conservation cropping. To overcome the training gap of SCB officers on the agronomic aspects of conservation cropping, the SCB set up training workshops (Keith 1988; Ward 1988). Workshops on machinery management and operation, for example, gave officers greater competence and confidence in working with farmers and local networks on stubble mulching and no-tillage systems. This greatly enhanced the effort to extend or expand conservation cropping on the Downs.

The identification of farmers' fallow management practices and constraints in the 1982 study (Chamala et al. 1983) also facilitated developing a coordinated program. Based on information about fallow management practices, officers established a priority list of problems (Keith 1988). For instance, it was clear that the profitability of chemical weed control was a major issue to farmers. Agriculture Branch administrators immediately sought funds for the purchase of equipment to determine the comparative cost-benefits of cropping under different tillage systems. The studies were also designed to involve farmers in the trials and their evaluation (Childs 1988).

Due to the diversity of farming systems in central Queensland as well as the lack of a uniform extension strategy, field supervisors initially developed different approaches to the establishment of reduced tillage systems. Although farmers on the flat plains southwest of Dalby rather quickly recognized and began developing conservation cropping systems, few of the upland farmers in the district, who Lindzey Ward had first tried to interest in stubble mulching, had accepted these principles or practices (Marshall et al. 1988).<sup>17</sup> Beginning in 1983, DPI officers developed a program to encourage upland farmers to use conservation cropping of summer opportunity crops through improving departmental officers' conservation cropping expertise and developing a nucleus of farmers interested in such techniques who could network with other farmers. Field officers selected demonstration sites in different geographic areas. Officers' expertise grew as their experience expanded. Farmers in a 5 to 10 km range of the initial sites were invited to the field



day and a farm walk. The range of farmers invited expanded as sites were moved annually. But, few seemed interested in conservation cropping, which disappointed the supervising field officer. In the end, however, a small group (network) of farmers became interested in working with advisors to construct workable conservation cropping systems.

On the southeast Darling Downs, the general extension approach was to carry out agent-farmer studies. Agriculture Branch and SCB officers located farmers (e.g., Rod Peterson and Colin Bell<sup>18</sup>) who were interested in cooperating on a study of chemical weed control. Although the agent(s) had a research agenda, he (they) also determined what problems the farmer was particularly interested in, and the experimental trials were designed with the farmer's involvement. The trial results thus were valuable to both the officers and the farmer.<sup>19</sup>

Meanwhile, Agriculture Branch and SCB officers held field days (etc.) and worked with networks of farmers around each innovative farmer to demonstrate the benefits of the trials and to engage other farmers in tillage system reconstruction on their own farms (Marshall et al. 1988; Childs 1988). From 1984 to 1988, two agent/farmer-led networks in the southern Downs and three in central Queensland were involved in the construction of conservation cropping systems. When a network of farmers had progressed to the stage that they could continue to adapt the systems on their own, field officers shifted their attention to other innovative farmers and established new networks.

The experimental/demonstration trials, which ran several years, benefitted both branch officers and the cooperating farmer. Other farmers in the network also set up their own trials, which the group discussed. In addition to testing various technical practices (e.g., various herbicide combinations and low-rate chemical applications), the Agriculture Branch's primary objective was to determine "the minimum effective cost of herbicide [weed] control" (Childs 1988). Results of the field studies provided the basis for development of a Reduced Tillage Fallow Management Program. The advisory aim was to assist farmers in developing cost-effective weed control and profitable crop yields as well as to save soil. This emphasis on economic profitability of the tillage-cropping system was more encompassing than conservation tillage on which the SCB focused.

Between 1978 and 1981 in the South Burnett, SCB developed satisfactory conservation cropping systems on two pilot farms using ridge-tillage methods with peanuts and other horticultural crops (Marshall et al. 1988; Begbie 1988; Keith 1988). By 1981, approximately thirty farmers in the area had begun using some or all of the system practices. These farmers became the focus of further tillage and cropping system

development, which entailed the use of stubble mulching machinery and herbicides in raising peanuts and other horticultural crops. A primary aim was to adapt the system to different types of soils. While continuing to conduct development work with the thirty "common-interest" cooperators, SCB officers after 1985 began trying to disseminate conservation cropping information to other farmers in the area through media, farm walks, tours, field days, and the like. However, as time went on, it became clear that other farmers who were smaller or were not primarily raising horticultural crops were not constructing such complex systems as had been developed on the thirty pilot farms.

In 1988, field officers changed the extension strategy to the formation and support of common-interest, conservation cropping development groups. That is, field officers sought to work with groups of farmers interested in solving problems in the utilization of specific practices (e.g., herbicides, stubble retention). When farmers felt they were able to utilize a particular practice, they would decide to shift attention to another constraint. New tillage and cropping systems thus evolved slowly.

In the region along the Queensland coast from Bundaberg to Ipswich, SCB officers in the early 1980s decided to use the agent-led pilot farm approach, which at that time seemed to be a successful approach, to help farmers develop conservation cropping systems. Discussion groups, field days, and farm walks were held around the research trials, which were designed to develop appropriate systems on pilot farms (Begbie 1988). Although substantial numbers of farmers attended these events, few either could adopt the trial practices or were able on their own to construct workable tillage systems on their farms.

There were several difficulties (Begbie 1988). One was that the pilot demonstration farmers tended to be the elite farmers, whereas the other farmers had less capital or were more risk-averse. The second stemmed from the notion, received from traditional diffusion theory and implicit in this extension approach, that the systems could and would be copied (rather than reconstructed). This false concept led soil conservation and agricultural field officers to focus on solving the problems of the pilot farmers, who were usually larger and more innovative, and largely to ignore the problems of the other farmers.<sup>20</sup>

Finally, the idea that it was a simple matter to establish systems in other areas where the weather, soils, and crops differed also made some field officers overconfident of positive benefits from field trials. When cooperating farmers' crops, which had been treated with herbicides, failed due to poor seasonal or other conditions, the field officers promoting the trials felt they had lost credibility and were reluctant there-

after to engage in further developmental work (Begbie 1988). The advisory officers were further handicapped in working collaboratively with farmers on developmental problems by an advisory style, in which they had been trained, that emphasized the transfer of knowledge to the uninformed rather than collaboration with them in problem solving. For their part, farmers in areas with riskier seasonal conditions were not able to adapt the concept of "opportunity double cropping," which farmers on the Downs had developed to use the moisture saved with zero-till methods, in growing another crop.<sup>21</sup>

When SCB administrators realized that this extension approach was not helping farmers solve the development problems associated with conservation tillage systems, they changed to a farmer-led extension method. This method was modeled on a group problem-solving approach that had been developed and successfully used during the 1960s to help farmers adopt improved farming technology (see Tully 1966).<sup>22</sup> In 1984, they began contacting landholders (farmers) who field officers thought might have the most interest in trying new conservation tillage practices (Begbie 1988). These farmers were formed into a farmer-led problem-solving group. Field officers helped the group set up joint farm demonstrations of herbicides on various crops and other residue-moisture-saving techniques in which the farmers were interested as a substitute for cultivation in summer fallow. The trial results then became the focus of group discussion and evaluation. After 2 or 3 years' guidance by the field officer, this group (network) continued to deal with evolving problems of the new tillage system entirely on its own, procuring expert advice when the group felt it was needed. The supervising field officer then established another farmer-led problem-solving group.

The objective was to help farmers develop confidence in their ability to analyze problems, which they had with new techniques, to find workable solutions, and to sustain an interest in developing improved tillage systems. This enabled farmers to construct, step by step, a new tillage and cropping system that they could manage. Farmers with mixed winter and summer crops developed different tillage systems than farmers with mixed crop and livestock farming systems (Begbie 1988). This extension approach differs substantially from the agent/farmer-led approach used on the Downs and is radically different from the traditional agent-led or "top-down" approach in which the field officer defines the farmer's problem and provides the solution for him. By 1988, Agriculture Branch and SCB officers in all districts, despite the diverse initial approaches, concluded that working with groups of farmers with "common interests" in solving particular conservation cropping

problems was the most effective method of helping farmers construct workable systems (Marshall et al. 1988).

*Conservation Cropping in the 1990s: Social Movements, Policies, and Institutional Developments*

The spread of conservation tillage and cropping in Queensland during the 1990s has been impacted by social movement, policy, and institutional developments as well as by drought. Not all of the forces, especially drought conditions, have been supportive of expansion of conservation tillage, and it seems likely that the movement may have lost momentum, although data are lacking to assess development trends.

Earlier (chapter 4) it was pointed out that soil erosion became recognized as a public problem in Australia during the 1930s. Environmental and "green" activism flowered in Australia as quickly as in the United States, and the attitudes of farmers reflected these changing cultural currents. By 1980, surveys of farmers on the Darling Downs in Queensland indicated that most recognized soil erosion as a serious problem, placed high value on stewardship, and felt that conservation practices were profitable (Chamala et al. 1983; Rickson et al. 1987; Vanclay 1992). Although few were then stubble mulching satisfactorily or using herbicides to reduce tillage, most had taken some steps, notably constructing contour banks on sloping fields, to control the most obvious manifestations of erosion. Doubtless, their efforts to control erosion, as well as the difficulty of assessing less obvious erosion events, help explain a widespread lack of concern with erosion on their own properties while believing that erosion was a problem generally.<sup>23</sup>

Sensitivity to claims of environmentalists of the harmful effects of chemical herbicides and pesticides was a constraint to constructing reduced tillage or zero-tillage systems in 1982 (Chamala et al. 1983). But, a decade later, Australian farmers generally (Barr and Cary 1992; Reeve and Black 1993) and on the Downs<sup>24</sup> had gained sufficient experience with chemicals to be more confident of using them safely. For example, 55 percent of a national survey of farmers agreed that the agricultural chemicals presently available were not harmful to health if the manufacturer's directions were followed (Reeve and Black 1993). Moreover, 53 percent agreed that sustainable agriculture would probably always require extensive use of agricultural chemicals. In view of this, it is not surprising that most farmers felt that the danger of environmental pollution from agricultural chemicals and the danger of chemical residues in food had been greatly exaggerated.

During the 1980s, the Australian public at large became increasingly concerned with environmental issues and with the role of agriculture in

land degradation (Lockie and Vanclay 1997). Following the Brundtland Report, *Our Common Future* (World Commission on Environment and Development, 1987), public debate shifted from land degradation to a broad concern with the sustainable use of natural resources in rural areas. Agriculture, of course, was the principal resource user. In 1989, the Prime Minister of the Commonwealth announced funding of a National Landcare Program (NLP) and declared the 1990s as the "Decade of Landcare." The focus of NLP was the organization of community-based, self-help groups dealing with local problems of sustainable land use, including soil, water, flora, and fauna. Project support in terms of money and advisory assistance was provided by private as well as public sources. The response was immediate, and by 1996, there were some 2,500 local landcare groups nationwide. It is evident that rural residents—landholders and environmentally concerned citizens—recognized varied possibilities in furthering their interests through participation in landcare groups.

A study of landcare groups in central Queensland (Morrisey and Lawrence 1997) indicates that the projects tended to be either promotional and informational, or action oriented. Landcare groups dominated by long-time farmers often focused on projects to increase public awareness of the positive environmental impacts of contemporary conservation farming practices.<sup>25</sup> Such projects flow, in part, from farmers' perceptions that "green" advocates had falsely portrayed farmers' environmental concerns, actions, and outcomes. In part, the promotional orientation was consistent with Landcare philosophy that increasing community awareness and understanding is central to sustainable land use. Other groups, dominated by the broader environmental interests of nonfarmers and part-time farmers often chose hands-on projects, such as planting trees or cleaning streams, that were of little interest to traditional farmers. In attempting to achieve objectives, local groups have been hampered by lack of leadership, conflicts, and shortage of funds. For these and other reasons, Morrisey and Lawrence (1997, 225) were pessimistic that the decade of Landcare will achieve its "major mission . . . [of bringing] about positive and effective change in the way natural resources are managed."

As emphasized earlier, through trial and error, the advisory services eventually developed an approach to spreading conservation tillage and cropping, which recognized the essential significance of networking with farmers in constructing successful systems. Although now recognized as an effective approach in innovating and extending complex systems (see chapter 10), it is less certain that a group or network approach is the approach most needed in sustaining these innovative systems. As noted,

farmers continually confront new difficulties with their conservation tillage systems. Group problem solving does not often provide a satisfactory way of dealing with such emergent problems due to the uniqueness of the individual farmer's problem. Even if several farmers have the same problem, formation of a group takes someone's time and effort, and a concerned farmer does not want to wait for a group to meet to have his problem considered. Farmers have found that they need the advice of knowledgeable "experts," or consultants, which can be obtained in a timely manner (Peterson 1995; Bell 1995; Newton 1995).

The problem is compounded by the financial crisis of reduced public funding of extension services. This has led DPI (1) to concentrate advisory services in designated centers, taking advantage of electronic media in the delivery of information, (2) to focus on providing consultation and advisory assistance to groups of clients (e.g., Landcare groups), and (3) to severely restrict off-site travel for consultation with individual farmers. This pressures farmers to sustain local networks with other knowledgeable farmers and/or obtain advisory assistance from private consultants. Notably, in the western plains where dryland cotton culture has developed, farmers have networked with private consultants to obtain technical and financial information. This may be a satisfactory solution in areas where there are ample numbers of private professional consultants.

Establishment of Conservation Farmers, Inc. is one of the most important developments, signifying first the presence and importance of the new culture of agriculture, and second the necessity of sustaining it through continual informational and networking support. As conservation cropping began to take off, advisory officers and leading farmers recognized the importance of having a central clearinghouse of information about conservation farming. In 1984, several farmers and agricultural advisors from the SCB and Agricultural Branches came together to form the *Conservation Farming Information Center* for the purpose of sharing information and promoting better farming practices that reduce soil erosion and increase crop yields. In 1988, the Center held its first Queensland conference—*Conservation Tillage in Queensland*—with funding support from the National Soil Conservation Project, Commonwealth Development Bank, and Consolidated Fertilizers Limited. The subsequent loss of DPI support due to the reduction in DPI budgets led the association to abandon the idea of operating an information center per se. Instead, it reorganized as *Conservation Farming Inc. (CFT)* and continues to promote farm management practices that help sustain long-term profitability. These include reduced tillage practices and new spraying techniques and cropping programs, which conserve soil moisture and prevent soil degradation. The association holds annual confer-

ences, field days, farm tours, and workshops, and provides informational literature to members.

### *Drought and the Asian Grain Market*

Australia is the driest continent, and inland areas in particular are subject to periodic drought. From 1991 through 1995, the Downs were abnormally dry, and crops were poor and farm income low. With opportunity cropping, farmers plant into moisture but do not plant when sufficient moisture is lacking. With poor crops, there was little or no surface residue to protect the soil. The low cash flow compelled farmers to restrict the purchase of inputs (e.g., herbicides) and make greater use of mechanical cultivation. Once better seasons returned, the Asian market collapse caused prices of cereals to drop, thereby prolonging the cash flow crisis. In this respect, weather and world markets have conspired to increase the difficulty of sustaining the new conservation tillage and cropping culture.

Although precise data on the extent of conservation tillage cropping in Queensland and the other Australian states is lacking, evidence of the demise of plow culture is widespread. Farmers generally recognize that retaining stubble, rather than burning it, is beneficial to soil health, and they increasingly recognize that frequent plowing and cultivation harm soil structure. Despite the gap between farmers' attitudes supporting conservation and their behavior (Vanclay and Lawrence 1995), the frequency of cultivation is declining, and the use of direct drilling, or no-tillage, is increasing in Queensland and in other states.<sup>26</sup> Steed et al. (1994, 244) report that "by 1992, most farmers in southeastern Australia cultivated much less than they did 20 to 30 years before," and that about 30 percent practiced direct drilling, and stubble retention was relatively common.

### Summary and Conclusions

During the past three decades, no-till cropping has twice taken off, as it were, in Kentucky. Following the initial takeoff in the late 1960s, there was an extended period of retrenchment and consolidation and then a second takeoff after 1990. Eight years after the start of the second takeoff, just under one-half of the cropland in Kentucky was no-tilled, and 70 percent of crops were grown under some conservation tillage system. Conservation tillage in Kentucky has not grown smoothly upward as might be expected in the ordinary diffusion of technology; instead, it has grown episodically. The growth of the new cultural pattern has been more like that of the spread of a sociocultural movement (e.g., an



environmental movement), responding to changes in economic and policy forces. As the fourth decade of the conservation tillage movement came to a close in Kentucky, a new tillage culture had become established for the production of most crops.

Because of the critical importance of both the farm bio-physical environment and the farmer's abilities in constructing a satisfactory system that he can manage on his farm, the critical factor in both the innovation and reinvention of the new agriculture has been the establishment of innovative networks. Only through such networks could the sustained resource support for constructing conservation tillage systems be provided. In network establishment, the initiatives of farm advisory services professionals and industry representatives have been critical. In Queensland, as well as in Kentucky, key farm advisors became early advocates of conservation tillage. Using traditional extension approaches—field trials and field days—they attracted curious farmers in the potential of the new methods. In itself, this approach was often insufficient to persuade farmers to make a sustained commitment to constructing new tillage systems. For the most part, only when the farm advisors and/or chemical company representatives identified key innovators and, either formally or informally, a number of other interested farmers who also became involved in attempting to construct satisfactory tillage systems, were the professionals successful in implanting a new indigenous culture.

The cultural innovators faced many new problems. They had to either construct or purchase, and often modify, equipment—tillers and planters—and learn how to use the new, unfamiliar machines. Different soils required different tillage methods. Farmers had to learn about herbicides and the arts of spraying. They encountered problems in controlling particular types of weeds (e.g., johnsongrass) and rodents and of seedling emergence in poorly drained or cooler soils. Some found minimum tillage the most satisfactory tillage system, especially for cereals. The evolutionary process of repetitive action-learning and adaptation in constructing satisfactory tillage systems has been long and often difficult. The difficulties with no-tilling crops caused some early innovators to shift to partial use of no-till and made others hesitant to try constructing their own no-tillage systems. Nevertheless, as farmers discovered the benefits of the new tillage and cropping systems, and as research and technology developments helped overcome constraints, and with the greater policy support for conservation tillage, most Kentucky and many Queensland farmers have become practitioners of the new tillage agriculture.

The historical patterns of conservation tillage and cropping development were different in Kentucky and Queensland. In Kentucky, after the



initial period of no-tillage innovation, research on no-tillage was principally carried out on the experiment station whereas trials in counties were primarily demonstration experiments designed to interest and instruct farmers in the methods and benefits. Such demonstrations in most Kentucky counties were followed by extensive advisory assistance to interested farmers. The local networks were mostly informal, depending largely on the initiative of interested farmers.

In Queensland, the farm trials were designed to provide field research information to the advisors and incidentally to provide information to farmers on the best methods. The agent-led trials often failed to elicit farmer commitments, except for the key demonstrator, to constructing new systems of stubble mulching. Sometimes, however, farmers subverted the research objective, ran evaluation trials themselves, and obtained the information they needed. Stubble mulching of both cereal and row crops was used by innovators for almost a decade on the Downs before reduced tillage trials, the use of herbicide substitution, was introduced. Although the initial efforts to spread conservation tillage were often frustrated by reliance on an agent-led extension model, the SCB and Agricultural Branches rather quickly discovered that the experimental learning of farmer-led networks was the most effective way of engaging farmers in constructing new tillage systems. This resulted in the formation of groups or networks that worked together for a period of years in solving conservation cropping problems. To an indeterminate degree, the establishment of informal networks in Australia has been handicapped by the change in the DPI's policy, limiting advisory assistance.

Different policy initiatives in the United States and Australia have resulted in somewhat different patterns of development. Initially, the Queensland government's initiative in acquiring and testing new tillage equipment enabled innovative farmers to develop successful stubble mulching methods. The declaration of the Downs as an Area of Erosion Hazard greatly facilitated the construction of conservation structures. Policy initiatives led to reduced tillage trials and the eventual development of successful reduced-tillage and zero-tillage cropping systems. But, drought, low grain prices, weak research support, and reduced direct advisory assistance to farmers struggling with difficulties with their conservation tillage systems have handicapped progressive adaptation of the new conservation culture.

In Kentucky, the research and advisory system support, along with the rapid development of mechanical and chemical technologies, were the principal strengths of conservation tillage development in the early years. Even so, market and policy changes and technical difficulties

constrained the development of no-tillage for many years. Since 1985, however, the policy initiatives of the 1985 Farm Bill have had a major impact on expanding conservation tillage and cropping culture.

## Notes

1. This was the first year that the *No-Till Farmer* conducted a survey of tillage systems used by farmers in each state. The estimates of “no-tilled,” “minimum-tilled,” and “conventionally tilled” acreage in each state were made by asking each state soil conservationist “to place all tillable acreage” into one of three categories using the following definitions:

No-tillage: Where only the intermediate seed zone is prepared. Up to 25% of surface area could be worked. Could be no-till, till-plant, chisel plant, rotary strip tillage, etc.

Minimum tillage: Limited tillage, but where the total field surface is still worked by tillage equipment.

Conventional tillage: Where 100% of the topsoil is mixed or inverted by plowing, power tiller or multiple discings. (Lessiter 1973)

In 1984, the definitions used in the annual surveys of state conservation officers were changed to the following:

No-tillage: Soil is undisturbed prior to seeding and planting is completed in a narrow seedbed usually 1–3 inches wide.

Minimum tillage: Any tillage and planting system other than no-till that retains at least 30% residue cover on the soil surface after planting.

Conventional tillage: Where topsoil is mixed or inverted by plowing, power tiller, multiple diskings or other means leaving less than 30% residue cover on the soil surface after planting. (Lessiter 1985)

In 1990, *No-Till Farmer* began reporting tillage data collected by the Conservation Technology Information Center (CTIC). CTIC gathered data on tillage practices at the county level by use of “county level personnel . . . [of the] USDA’s Soil Conservation Service, Cooperative Extension Service, Soil and Water Conservation Districts and local agricultural industry representatives” (Lessiter 1991).

2. The estimates of cropland treated with different tillage systems does not include “no-tilled” citrus crops in California and Florida or no-tilled pasture renovation (Lessiter 1973).

3. See chapter 9 and table 9.1.

4. see chapter 9 and table 9.1.

5. The roles of farmers and professional advisors in innovative networks during the innovation phase of conservation tillage are analyzed in chapters 5, 6, and 7.

6. Due to the personal relationships of Phillips and Davie with Hugh Hurst (the Pulaski County agricultural extension agent), the first no-till trials outside Christian County were established in Pulaski County.

7. Hugh Hurst (1998), functioning as Bluegrass Area agronomy specialist, recalls charging expenses for 1,500 miles' travel from one county demonstration site to another during the 1968 season.

8. Although the demand for no-till demonstration trials in Kentucky has gradually subsided, it remains an effective method of demonstrating the effectiveness of no-tillage methods. As recently as 1994, the county agent in a Kentucky mountain county where little corn is grown requested the first ever no-till demonstration trial (Bitzer 1995).

9. Joe Nay (1992) and Norman Dick (1992), early no-till innovators in Oldham County, attended the 1966 field day as did Bucky Teater (1992) who started no-tilling in Todd County in 1967.

10. USDA (1979b; charts 25 and 27).

11. Farmers generally tended to increase the acreage farmed during the 1970s. Christian County farmers who had not tried no-tillage increased the average farm size by 37 percent (Choi 1981).

12. *The Progressive Farmer* and other farm papers in the spring and summer issues annually featured the latest information on chemical weed and insect treatments, application methods, and the like. For example, the January 1976 (pp. 19, 31) issue of *The Progressive Farmer* carried a story ("Their Land Produces 150%") on Harry and Lawrence Young's three-crops-in-2-years system, which acknowledges that they "see weed control as the No. 1 problem that must be whipped for anyone considering no-tillage production," and indicates the chemical treatments the Youngs use. The May 1977 issue of *The Progressive Farmer* headlines "How to Lick Bad Weather Weed Problems," acknowledging that "[e]ven the best planned chemical weed control program occasionally falls victim to bad weather," and listing recommended ways of dealing with weather complications. In a pattern that was not exceptional, the January, March, May, and June 1979 issues of *The Progressive Farmer* carried articles on "What's the Best Tool for Incorporating Herbicides?" "Tackle Tough Soybean Weeds with Directed Spray," "Apply Your Herbicide at Pin-Point Rates," and "New Herbicide Rigs Make the Scene," respectively.

13. Thirty-six percent of the Christian County farmers who had stopped using no-tillage in 1977 said they would not recommend no-tillage to their friends, compared to 4 percent of those who were using no-tillage systems (Choi 1981). Carlson and Dillman (1986) pointed out that "another farmer in the county" had been one of the information sources for 90 percent of the nonusers of no-tillage and that both the "undecided" and those opposed to future use of no-till mentioned weed control and higher costs as the principal factors in their decisions.

14. All through the 1970s, the index of prices received by farmers exceeded the index of prices paid. See USDA (1982, chart 21).

15. The impact of the CRP program on tillage practices is discussed more fully in chapter 9.

16. Tarek Kamel, SCB, and Peter Wiley, Agriculture Branch, were the officers in charge of the joint program.

17. See chapter 5.

18. Ken Bullen (Agricultural Branch) and Tom Crothers (SCB) worked with Rod Peterson.

19. The research aims were (a) to determine “the most appropriate alternatives to current ‘conventional’ fallow management practices, (b) to improve farm returns by optimising crop yields and by improving the likelihood of double cropping or opportunity cropping through improved soil moisture retention” (Marshall et al. 1988). By consulting with ICI and Monsanto field representatives, who were conducting their own herbicide trials on farmers’ fields, Agriculture Branch and SCB officials quickly amassed information about effective chemical weed control methods (Childs 1988; Guthrie and Frazier 1988).

20. One SCB administrator assessed the failure of their former extension approach this way: “[We discovered that] the pilot farm thing wasn’t going to be a real go. The practice of using pilot farms at that stage was a legitimate technique that was relying on the old diffusion process. . . . The first year you get 6 guys, the next year 12, then 24 are involved. But, we never got beyond the 6” (Begbie 1988).

21. Innovative farmers on the Downs also had to largely abandon the idea of opportunity double cropping when seasonal conditions turned drier during the 1990s (Bell 1995; Peterson 1995).

22. As a result of DPI officer training under Dr. Joan Tully in the Department of Agriculture, University of Queensland, and in consultation with Dr. Tully, the Training Section, Information and Training Branch, DPI in 1975 developed a training manual on “Rural Discussion Groups” for use by field officers in working with rural landholders.

23. Awareness of erosion as a hazard on the Darling Downs was heightened by declaration of the thirteen shires as an Area of Erosion Hazard. The inverse relationship between distance and perception of seriousness of erosion is discussed by Rickson et al. (1987).

24. Interviews with conservation tillage innovators in 1995; see chapter 7.

25. There are exceptions to this tendency. The first project funded for Clifton Landcare enabled Peterson (1995) to build a trash planter on a chisel plow frame for farmers in the shire to use as desired in mulch or zero-till planting.

26. The Kondinin Group National Agricultural Survey in 1995 found that 55 percent of Australian farmers had substituted herbicides for at least one cultivation; only 24 percent said they were still using conventional tillage methods (*Farming Ahead with the Kondinin Group*, No. 63, March 1997, pp. 34–35).

# 9

## Reconstructing the Farm Landscape: The Spread of Conservation Tillage in the United States

*National action to conserve the soil resources . . . must not only deal with soil erosion and related physical phenomena but also cope with the complex economic and social considerations that affect land use.*

—H. H. Bennett (1939, 313)

Although farmers in the United States began experimenting with mulches to reduce wind and water erosion early in the twentieth century, intensive research on stubble mulching for erosion control was not initiated until the 1930s (McCalla and Army 1960). Since then, researchers have continued to experiment with reduced tillage methods and to apply the principles to different types of crops. Farmers collaborated in the development of conservation tillage and cropping methods through their own experimental trials, aiming to develop tillage systems that were operationally manageable on their own farms. Although tillage research was still in its infancy, the successful construction of conservation tillage and cropping systems in the 1950s and 1960s inaugurated a cultural revolution in “methods of soil preparation, crop planting, and general soil management. In doing so, these procedures changed the way people perceived the soil, [and] challenged conventional plow-based farming practices dating back into antiquity” (Nelson 1997, 71–72). The revolution has elicited a more organic philosophy of management by farmers that recognizes and utilizes many interrelationships among climate, soils, and plants for cropping success, which contrasts with the engineering philosophy of crop management that is characteristic of plow culture.

In chapter 8, we analyzed the pattern of growth of conservation cropping in Kentucky and Queensland. In this chapter, we focus exclusively on the United States, analyzing the spread of conservation tillage systems nationwide. This growth, especially of no-tillage cropping, is found

to be episodic: A takeoff period is followed by a period of contraction; this in turn is followed by a period of slow growth, and most recently a period of rapid expansion. Then we examine each of these periods, analyzing the important contextual forces affecting the expansion of conservation cropping.

### Conservation Tillage Trends

Growth or progress in conservation tillage can be measured in several ways—number of users, acreage, or proportionate utilization. The most extensive information on the use of conservation tillage in the United States is provided by periodic surveys of acres of cropland managed under specified tillage regimes. A 1959 survey by the U.S. Soil Conservation Service indicated that 20.4 million acres of cropland were managed in such a way “as to keep protective amounts of vegetative material on the surface of the soil” from harvest until the next crop is seeded (McCalla and Army 1960, 126). These methods of cropland management had already become an important feature of cropping on the Great Plains, where 86 percent of this acreage was located. The appeal of conservation tillage continued to grow, and cropland managed by such methods increased by 46 percent, to 29.7 million acres, in 1972 according to data reported by *No-Till Farmer*.<sup>1</sup> This represented 15 percent of the nation’s cropland.

The annual reports by *No-Till Farmer* of acres tilled by various methods—no-tilled, minimum tilled, conventional tilled—by state permit analysis of the numerical and proportionate growth in the acres under conservation tillage practices.<sup>2</sup> These data indicate that after 1972 the acreage managed under minimum tillage continued to climb until 1982, when it accounted for 100.3 million acres, 31.7 percent of the nation’s cropland (table 9.1). Since then, the minimum-tilled acreage has tended to decline to the point that 60 million or less acres have been minimum tilled each year since 1993.

However, the trend in minimum or mulch tillage is only part of the story. Using an expansive definition of “no-till” that included various tillage methods that worked 25 percent or less of the surface area, the *No-Till Farmer* reported that 3.3 million acres (1.6 percent) of all crops were no-tilled in 1972.<sup>3</sup> With more than one-seventh of the nation’s cropland under some type of conservation cropping, the cultural revolution in cropping agriculture to which Nelson (1997) referred was already well underway.

Since 1972, the acreage no-tilled or ridge-tilled, although episodically rising and falling, has increased nearly sixteen times. (See table 9.1 and

Table 9.1. Trends in Tillage Systems in the United States: 1972–1998 Tilled Acreage (Million).

Year	No-Till†			Ridge Till†			Minimum Till‡			Conventional			Total	
	No.	(%)		No.	(%)		No.	(%)		No.	(%)		No.	(%)
1972	3.3	(1.6)	—	—	—	—	26.4	(13.0)	173.0	(85.4)	202.7	(100)		
1973	4.9	(2.0)	—	—	—	—	39.0	(15.8)	204.0	(82.2)	247.9	(100)		
1974	5.4	(2.4)	—	—	—	—	41.3	(15.4)	221.0	(82.5)	267.8	(100)		
1975	6.5	(2.4)	—	—	—	—	49.7	(17.9)	221.1	(79.7)	277.3	(100)		
1976	7.5	(2.7)	—	—	—	—	52.1	(18.3)	224.5	(79.0)	284.1	(100)		
1977	7.3	(2.4)	—	—	—	—	62.7	(21.0)	228.6	(76.6)	298.6	(100)		
1978	7.1	(2.4)	—	—	—	—	67.7	(22.6)	224.1	(75.0)	298.9	(100)		
1979	6.7	(2.2)	—	—	—	—	78.5	(25.5)	222.2	(72.3)	307.4	(100)		
1980	7.1	(2.4)	—	—	—	—	82.9	(27.5)	211.1	(70.1)	301.1	(100)		
1981	9.2	(2.9)	—	—	—	—	89.8	(28.3)	218.3	(68.8)	317.3	(100)		
1982	11.6	(3.7)	—	—	—	—	100.3	(31.7)	204.2	(64.6)	316.1	(100)		
1983	11.7	(4.0)	—	—	—	—	79.6	(26.8)	205.1	(69.2)	296.4	(100)		
1984	14.8	(4.4)	—	—	—	—	85.5	(25.8)	231.3	(69.8)	331.6	(100)		
1985	17.9	(5.5)	—	—	—	—	86.9	(26.4)	224.2	(68.1)	329.0	(100)		
1986	14.4	(4.8)	—	—	—	—	83.2	(28.1)	198.7	(67.1)	296.3	(100)		
1987	12.5	(4.3)	—	—	—	—	73.5	(27.1)	186.5	(68.6)	272.6	(100)		
1988	12.9	(4.7)	—	—	—	—	75.1	(27.6)	184.2	(67.7)	272.2	(100)		
1989	14.1	(5.1)	—	—	—	—	57.6	(20.6)	207.9	(74.3)	279.6	(100)		
1990	16.6	(5.9)	—	—	—	—	56.4	(20.1)	207.7	(74.0)	280.7	(100)		
1991	20.6	(7.3)	—	—	—	—	58.5	(20.8)	202.1	(71.9)	281.2	(100)		
1992	28.1	(9.9)	—	—	—	—	60.6	(21.4)	194.2	(68.7)	202.9	(100)		
1993	34.8	(12.4)	3.5	(1.2)	—	—	62.3	(22.1)	181.0	(64.3)	281.6	(100)		
1994	39.0	(13.7)	3.6	(1.3)	—	—	56.7	(20.0)	184.6	(65.0)	283.9	(100)		
1995	40.9	(14.7)	3.4	(1.2)	—	—	54.5	(19.6)	179.7	(64.5)	278.5	(100)		
1996	42.9	(14.8)	3.4	(1.2)	—	—	57.5	(19.8)	186.4	(64.2)	290.3	(100)		
1997	46.0	(15.6)	3.8	(1.3)	—	—	60.0	(20.4)	184.9	(62.7)	294.7	(100)		
1998	47.8	(16.3)	3.5	(1.2)	—	—	57.9	(19.7)	184.1	(62.8)	293.3	(100)		

Source: From *No-Till Farmer* for years 1972–1977; for 1998, from CTIC 1998 Survey Report.

\*For 1972–1982 up to 25 percent of surface area could be worked. Includes no-till, till-plant, chisel plant, rotary skip fill, etc. For 1984–1998, “no-till” is defined as planting in a narrow unprepared seedbed usually 1–3 inches wide.

†For 1993–1998, ridge-tills recorded separate from minimum or mulch tillage.

‡Limited tillage over the entire surface. 1984 and subsequent years, any system other than no-till that retains 30 percent residue cover. For 1994 and following years, this is designated as “Mulch Till.”

Figure 9.1. Trends in tillage systems in United States: 1972–1998.

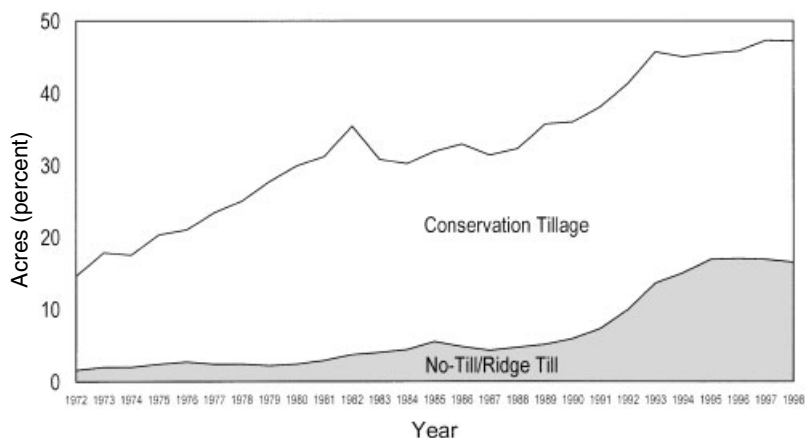


fig. 9.1.) The large increase in the latter two types of tillage systems, which best protect cropland, more than compensates for the decline since 1982 in minimum-tilled acreage. Management of the nation's cropland under some type of conservation tillage has thus continued its slow advance, reaching 37 percent of all cropland in 1998. In one-fifth of the states and Puerto Rico, conservation tillage and cropping had by then become the conventional tillage system of farmers.<sup>4</sup>

The growth in no-tillage cropping, and in the interplay between no-tillage and minimum tillage, in the slow expansion of conservation cropping is the main story of the revolution in agriculture during the past 50 years in the United States.

Although no-tillage cropping was of relatively minor importance nationally in 1972, substantial proportions of the cropland in several states were already being managed with no-tillage: West Virginia (13 percent), Virginia and Pennsylvania (14 percent each), Kentucky (26 percent), and Maryland (36 percent). Clearly, in these five states, no-tillage agriculture had already become established.

The national trend data indicate that the initial enthusiasm for no-tillage continued to build through 1976 when 7.5 million acres (2.7 percent) of cropland in the United States was no-tilled. Of equal significance, minimum-tilled acreage also continued to expand. By 1975, one out of every five crop acres were conservation tilled, either minimum tilled or no-tilled. Clearly, the conservation tillage movement was growing.



When 5 percent of the cropland in a state is managed under a particular tillage system, we assume that the system has become a viable, local tillage culture. Using this benchmark as an indicator of the viability of no-tillage in a state, by 1976 seven more states—Delaware, Indiana, Massachusetts, Nebraska, New Jersey, and North Carolina—were added to the five initial states that had reached the *takeoff* stage in no-tillage agriculture. The appeal of no-tillage at this early stage of its development was clearly primarily to farmers in the middle states, those mainly along the eastern seaboard and westward to Kentucky and Nebraska.

From 1977 to 1980, a short period of *consolidation and retrenchment* in the utilization of no-tillage occurred nationally despite the continued spread of the system to new states. Nationally and in many states, no-till acreage stabilized or declined both numerically and proportionately during this period. Many farmers discovered that there were problems with their no-till systems (e.g., perennial weeds) that they could not handle satisfactorily and switched to a strategy of minimum tillage and/or occasional no-tillage. In 1980, only 7.1 million acres (2.4 percent) of cropland were no-tilled, 5 percent less than in 1976. However, 82.9 million acres (27.5 percent) were minimum tilled, and farmers used some conservation tillage practice in growing crops on three out of every ten acres of cropland in the United States.

Although this was a period of retrenchment in no-tillage in most of the states that had experienced early growth, no-tillage continued to take off in areas and states in which farmers were just beginning to construct innovative systems. Consequently, between 1977 and 1980 a take-off in no-tillage occurred in four more states—Georgia, Nevada, Ohio, and Tennessee. It is apparent that no-tillage systems were spreading outward in wavelike fashion from the centers of early development. However, there was a westward jump to Nevada, which was the first clearly western state in which no-tillage became an important cropping system.

The 1980s marked a decade of *gradual expansion* in conservation tillage generally and no-tillage in particular. At the beginning in 1981, 9.2 million acres (2.9 percent) of cropland were no-tilled, and 89.8 million acres (28.3 percent) were minimum tilled. The 99 million acres of crops under conservation cropping systems were a record high. Although no-till acreage continued to rise during the 1980s to 16.6 million acres by 1990 (5.9 percent), double the 1981 proportion of cropland under no-tillage, minimum-tilled acreage declined both absolutely and proportionately, so that only 73.2 million acres of crops (26 percent) were raised in 1990 with conservation (reduced) tillage systems. As discussed more fully later, the advent of the Conservation Reserve Program (CRP) in the 1985 Farm Bill had much to do with this trend. It is

apparent that while some farmers were gaining mastery of the intricacies of no-tillage systems and making these systems part of their normal farming operations, other farmers decided to transfer eligible cropland, which they had minimum tilled, to conservation reserve.

Although “gradual expansion” best describes the status of no-tillage nationally, the revolutionary tillage system was retrenching in some states where takeoff had earlier been achieved, and rapidly expanding, or was taking off in still other places. During the 1980s, for example, eleven more states reached takeoff status in no-tillage—Alabama, Alaska, Connecticut, Illinois, Michigan, Missouri, Montana, New Hampshire, Puerto Rico, Rhode Island, and South Carolina.

The succeeding years of the 1990s, as the data in table 9.1 indicates, have been marked by a *rapid expansion* in conservation tillage. Although cropping under no-tillage systems (no-till and ridge-till) has increased rapidly, the proportionate use of minimum or mulch tillage has remained relatively stable, and the proportionate use of conventional tillage has dropped from 74 percent to 64 percent (a 10 percent decline). In 1998, 47.8 million acres (16.3 percent) of cropland was no-tilled, and 3.5 million acres (1.2 percent) of crops were ridge tilled, triple the 16.6 million acres in 1990. With an additional 57.9 million acres (19.7 percent) of crops produced with mulch tillage regimes, the 106.9 million acres (37.2 percent) under conservation tillage systems in 1998 were only slightly lower than the peak achieved in 1997. This was nearly three out of eight of the cultivated acres in the United States.

The rapid expansion of no-tillage during the 1990s occurred not only in states in which no-tillage had taken off much earlier, but also at the margins where the revolutionary system of tillage only recently had taken off. Between 1990 and 1998, Arkansas, Colorado, Iowa, Kansas, Louisiana, Minnesota, Mississippi, New York, North Dakota, South Dakota, and Wisconsin were added to the list of states in which 5 percent or more of the cropland is being no-tilled or ridge-tilled. By 1998, no-tillage and ridge-tillage had taken off in thirty-seven of the fifty states and Puerto Rico. The expansion of no-tillage in the Great Plains states is indicative of successful development of no-tillage in small-grain growing areas. Meanwhile, no-tillage and ridge-tillage systems held record, or near record, levels of utilization in states that were early adopters of the revolutionary system—Kentucky (48 percent), Maryland (48 percent), Pennsylvania (21 percent), Virginia (37 percent), and West Virginia (38 percent).

In the early 1950s, plow culture reigned; farmers were just beginning to experiment with stubble mulching. During the next two decades, however, farmers began using conservation tillage methods in raising

crops on about 15 percent of the nation's cropland. Two decades later, in 1990, nearly 25 percent (an increase of 10 percent) of the nation's crops were raised under conservation tillage methods. In an important respect, the progress made during this latter period was even greater than the percentage change would suggest because the definition of conservation tillage became stricter and the reporting became more reliable. But, most importantly, the advance of conservation cropping culture in the first 8 years of the 1990s was greater than during the previous 20 years. In nine of the states and Puerto Rico, conservation tillage systems became conventional (i.e., used on more than 50 percent of cropland). At the other extreme, in only three states—Rhode Island, Connecticut, and Hawaii—had some form of conservation tillage system failed to reach the 5 percent take-off level. As the century came to a close, therefore, plow culture no longer held unchallenged sway, but was in retreat to methods that better protect soil quality.

### *Regional Trends*

The *Conservation Technology Information Center (CTIC)* has used the USDA Economic Research Service (ERS) regional division of the United States and Puerto Rico as the basis for reporting the regional utilization of tillage systems. Table 9.2 indicates the spread of conservation tillage in the eleven ERS regions since 1972. At that relatively early stage in the conservation tillage revolution, the northeast region, with 41 percent of cropland managed under the new systems of agriculture, clearly led the way in its acceptance.<sup>5</sup> Significant changes also had occurred in the Appalachian and northern Plains regions. No-tillage agriculture had made the greatest advance in Appalachia and the Northeast. At the same time, few farmers in the mountain, southeast, or Delta states had become interested in no-tillage or in conservation tillage agriculture generally.

Although the appeal of no-till had become evident in most regions by 1976, it had spread with particular rapidity in the Appalachian and northeast regions and had made a significant advance for the first time in the corn belt. Between 1972 and 1976, many more farmers in the Appalachian, corn belt, mountain, pacific, and southeast regions also became interested in minimum or mulch tillage. At the same time, there was an apparent significant decline in minimum tillage in the northeast region.

The years 1976 to 1980 were a period of consolidation and retrenchment in no-till cropping nationally, and the retreat of its appeal is evident in most regions, but most especially the corn belt. Notable exceptions to the retrenchment were the northeast and southeast regions,

Table 9.2 Regional Trends in Conservation Tillage Acreage 1972–1998.

Region	No-Till	Ridge-Till	Mulch-Till	Minimum Conventional	Total (Million Acres)
1972 (Percent)					
Appalachian	10.5	—	15.3	74.2	100.0 (10.0)
Caribbean	—	—	100.0	—	100.0 ( 0.0)
Corn belt	3.2	—	12.3	85.5	100.0 (55.8)
Delta states	—	—	—	—	100.0 (10.4)
Lake states	0.9	—	11.5	87.6	100.0 (15.2)
Mountain	0.3	—	8.5	91.2	100.0 (18.2)
Northeast	7.1	—	34.3	58.6	100.0 ( 7.6)
Northern Plains	0.6	—	20.2	79.2	100.0 (38.2)
Pacific	—	—	16.8	83.2	100.0 (13.9)
Southeast	0.7	—	0.1	99.2	100.0 ( 7.9)
Southern Plains	0.2	—	7.7	92.1	100.0 (25.7)
1976 (Percent)					
Appalachian	13.9	—	25.5	60.6	100.0 (13.2)
Caribbean	—	—	7.5	92.5	100.0 ( + )
Corn belt	5.1	—	21.7	73.2	100.0 (70.2)
Delta states	0.6	—	5.1	94.3	100.0 (14.4)
Lake states	1.9	—	12.8	85.3	100.0 (29.0)
Mountain	0.1	—	16.8	83.1	100.0 (22.0)
Northeast	10.3	—	18.0	71.7	100.0 ( 7.7)
Northern Plains	0.7	—	17.9	81.4	100.0 (71.4)
Pacific	1.1	—	36.5	62.4	100.0 (11.3)
Southeast	1.8	—	18.7	79.5	100.0 (12.0)
Southern Plains	0.7	—	8.6	90.7	100.0 (30.7)
1980 (Percent)					
Appalachian	12.3	—	29.6	58.1	100.0 (15.2)
Caribbean	0.3	—	25.1	74.6	100.0 ( 0.6)
Corn belt	2.6	—	34.4	63.0	100.0 (74.8)
Delta states	0.7	—	12.5	86.8	100.0 (15.5)
Lake states	1.2	—	19.6	79.2	100.0 (30.7)
Mountain	0.8	—	28.3	70.9	100.0 (22.8)
Northeast	11.8	—	24.7	63.5	100.0 ( 7.8)
Northern Plains	1.1	—	30.3	68.6	100.0 (79.7)
Pacific	0.3	—	18.0	81.7	100.0 (12.3)
Southeast	5.7	—	39.1	55.2	100.0 (12.4)
Southern Plains	0.2	—	14.9	84.9	100.0 (29.2)

where no-tillage continued to expand. Except for the Pacific region, farmers in all the regions participated in the general advance of mulch tillage cropping during this period. Mulch tillage again established a foothold in the Caribbean region; significant expansion also occurred in the corn belt, mountain, northern Plains, and southeast regions.

Table 9.2. *Continued.*

Region	No-Till	Ridge-Till	Minimum Mulch-Till	Conventional	Total (Million Acres)
1990 (Percent)					
Appalachian	23.5	—	17.1	59.4	100.0 (12.3)
Caribbean	18.9	—	29.7	51.4	100.0 ( + )
Corn belt	9.4	—	23.5	67.1	100.0 (76.1)
Delta states	4.3	—	6.3	89.4	100.0 (15.5)
Lake states	3.4	—	17.3	73.3	100.0 (31.5)
Mountain	3.7	—	20.5	75.8	100.0 (20.5)
Northeast	16.7	—	17.1	66.2	100.0 ( 8.2)
Northern Plains	3.1	—	23.6	73.3	100.0 (65.2)
Pacific	1.8	—	11.8	86.4	100.0 (11.1)
Southeast	4.6	—	9.0	86.4	100.0 ( 9.8)
Southern Plains	1.1	—	22.4	76.5	100.0 (28.6)
1998 (Percent)					
Appalachian	37.2	0.2	11.4	51.2	100.0 (14.2)
Caribbean	16.2	0.7	48.0	35.1	100.0 ( + )
Corn belt	27.6	0.4	19.8	52.1	100.0 (78.8)
Delta states	12.2	2.3	5.1	80.5	100.0 (15.7)
Lake states	10.1	0.5	20.5	68.9	100.0 (32.9)
Mountain	6.8	0.5	26.6	66.0	100.0 (20.9)
Northeast	22.2	0.1	16.7	61.0	100.0 ( 8.4)
Northern Plains	13.8	3.2	23.7	59.3	100.0 (71.4)
Pacific	3.1	—	18.2	78.7	100.0 (12.4)
Southeast	13.8	0.5	7.0	78.7	100.0 ( 8.9)
Southern Plains	2.7	0.6	21.2	75.6	100.0 (29.5)

Source: Data for 1970, 1976, 1980, 1990 from *No-Till Farmer*; 1998 from CTIC 1998 Survey Report.

During the 1980s, although no-tillage spread slowly in most of the regions, it spread with particular rapidity in the Appalachian, Caribbean, and corn belt regions. The Southeast was the only region in which no-till cropping actually declined proportionately. Although mulch tillage expanded in the Caribbean and southern Plains during this period, it declined as a proportion of the tillage systems used in all other regions.

Although no-tillage declined slightly in the Caribbean region and made only modest advances in southern Plains, Pacific, and mountain regions during the 1990s, this system of cropping grew rapidly in all other regions. Its spread in the Appalachian, corn belt, and northern Plains is especially notable.

The trends in regional utilization of mulch tillage during the 1990s, on the other hand, were quite varied. In the Appalachian and corn belt

regions, where large increases in no-tillage occurred, it is apparent that many farmers shifted from mulch tillage to no-tillage cropping. By contrast, in the lake, mountain, and Pacific states where no-tillage has made modest gains during this decade, there also were modest gains in mulch tillage. Mulch tillage also has made a substantial advance in the Caribbean during this decade.

Although ridge tillage, which *No-Till Farmer* first began recording separately in 1993, is widely represented in nearly all regions, its greatest appeal is to farmers in the Delta and northern Plains. Irrigated cotton growers in the Delta find it a useful system, and in the cooler northern plains, corn and soybean growers like the way the ridges warm and allow early spring planting. In fact, Nebraska farmers have made the greatest use of this tillage system. In 1998, 11 percent of the 16.2 million acres of Nebraska cropland was ridge tilled (an additional 19 percent was no-tilled).

The review of regional trends shows that farmers in the Appalachian and northeastern states were among the early leaders not only in no-tillage but also in conservation tillage systems generally and have continued to play leading roles throughout the conservation tillage revolution. However, with the great advance in conservation tillage systems made in the last decade, farmers in the corn belt and northern Plains became co-partners in conservation tillage leadership. Despite the progress of the last decade, however, the Delta, Pacific, southeast, and southern Plains are lagging areas in conservation tillage cropping.

### *Crops*

The initial development of conservation tillage methods aimed to help small-grain growers overcome problems of wind erosion, and farmers growing small grain in the plains area were the first to begin constructing successful conservation tillage systems. In the 1950s and 1960s, as earlier chapters have detailed, farmers began experimenting in the construction of conservation tillage systems for row crops, especially corn and soybeans. The data in Table 9.3 indicate that the advance of conservation tillage has been greatest with respect to these major crops. Its appeal has been greatest to those raising double-crop corn, soybeans, or sorghum, and full-season soybeans. These are crops in which the speed and moisture saving of no-till cropping is especially beneficial. Although substantial proportions of the full-season corn and sorghum crops in 1998 were grown with conservation tillage methods, clearly further progress can be made. This is also true with respect to the both the fall- and spring-seeded small-grain crops. Cotton is the other major crop in

Table 9.3. Tillage Systems by Crop, 1998.

	No-Till	Ridge-Till	Mulch-Till	Total Conservation Tillage	Conventional	Total (Million Acres)
	Percent					
Corn (full season)	16.4	2.9	19.6	38.9	61.1	100.0 (80.5)
Corn (double crop)	28.3	0.2	16.9	45.4	54.6	100.0 ( 1.1)
Small grain (spring seeded)	8.3	0.0	22.6	30.9	69.1	100.0 (33.5)
Small grain (fall seeded)	9.3	0.1	24.2	33.6	66.4	100.0 (47.8)
Soybeans (full season)	28.7	0.9	22.6	52.2	47.8	100.0 (66.6)
Soybeans (double cropped)	66.3	0.1	7.8	74.2	25.8	100.0 ( 6.2)
Cotton	4.9	2.2	5.3	12.4	87.6	100.0 (13.6)
Grain sorghum (Full season)	11.1	1.5	21.1	33.6	66.4	100.0 ( 9.3)
Grain sorghum (double cropped)	31.7	0.8	16.2	48.7	51.3	100.0 ( 0.6)
Forage crops*	10.2	n/a	13.9	24.1	75.9	100.0 ( 7.1)
Other crops†	4.6	0.3	12.9	17.8	82.2	100.0 (27.0)

Adapted from CTIC, 1998 Annual Survey Report.

\*Forage crops reported in seeding year only.

†Other crops include other vegetable crops, truck crops, peanuts, tobacco, sugar beets, etc.

which some progress in constructing successful conservation tillage systems has been made, but much further progress could take place.

### Spreading the Seeds of No-Till Systems

During the past four decades, farmers have constructed or reconstructed satisfactory no-tillage systems for growing different kinds of crops on various types of soils, in widely varied climates, and under different market and policy conditions. As the data indicate, however, these new systems have spread more rapidly in some places and times than others. Although the foregoing data reflect acres tilled rather than the number of adopting farmers, it seems evident that the advance of no-tillage over the past three decades in the United States, as has been the case in Kentucky, did not conform to a logistic, diffusion curve, which earlier studies of the trial use of new tillage practices have found (Choi

1981; van Es et al. 1986; Korsching et al. 1983). The historical data on acres tilled under no-tillage in the United States indicate that the pattern of actual growth has been episodic. The initial takeoff of no-tillage systems was followed by a period of consolidation or retrenchment. It is apparent that some farmers had difficulties; some cut back on the use of their new systems, and others, perhaps, reverted to conventional tillage. This was followed by several years of slow expansion and then, most recently, by a period of rapid expansion. These phases in the spread of no-tillage raise questions about the factors and processes that explain this episodic pattern of growth.

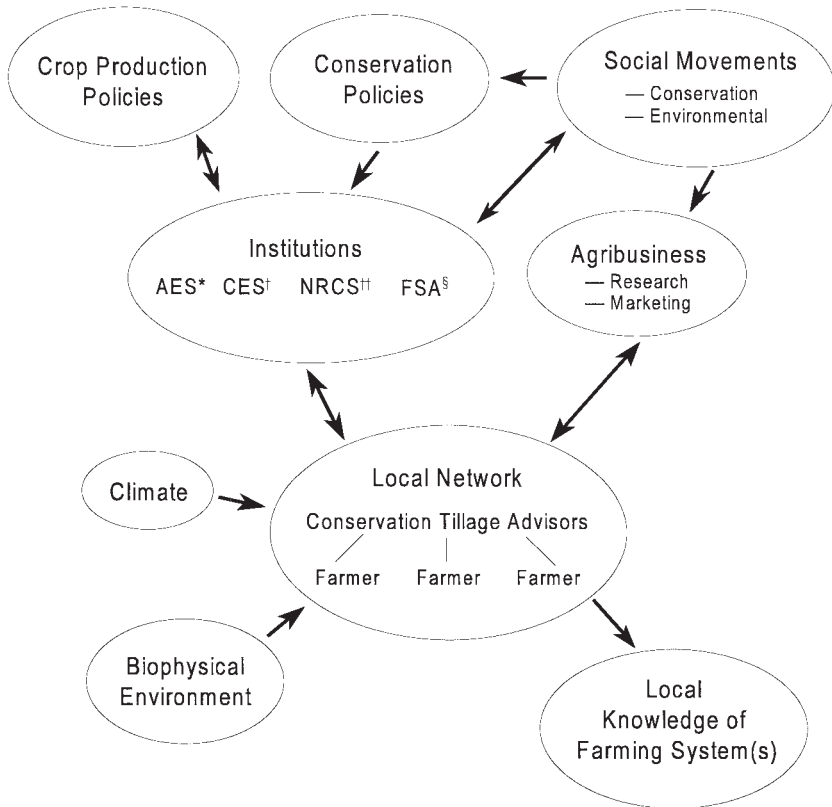
Farmers' "utilization" of conservation practices generally has been recognized by analysts as a process affected by many factors—social, economic, ecological, farm, and personal (e.g., Halcrow et al. 1982; Nowak 1984; Lovejoy and Napier 1986; van Es 1984). Although prior studies of conservation practice utilization have invariably treated adoption as an individual issue with the farmer at the receiving end of proven conservation practices, we have emphasized the importance of local networks in the innovation-adoption process. The local network of innovative-minded farmers and professional consultants is central to the successful construction of conservation tillage systems. First, in that conservation tillage systems represent solutions to a set of tillage and cropping problems, the local network with the farmer as the key problem solver is the locus of the process (Ashby et al. 1996; Chambers et al. 1989). Second, the local network provides the key resource support for individual innovators during the years they are "experimentally" constructing a satisfactory tillage system, and, third, it connects the local system with a global support network. Finally, the successful tillage and cropping systems of farmer members confirm the principles and practices as new "local knowledge." That is, the network affirms the establishment of a new farming culture. In this sense, the construction of innovative tillage/cropping systems, such as no-tillage, are network products. It follows that the key mechanism of innovation-diffusion of a complex system, such as no-tillage, is the establishment of innovative networks.

The conceptual model of the factors affecting innovative networks in the innovation-diffusion of conservation (tillage) cropping systems is presented in figure 9.2. Local innovative networks are directly affected by global network institutions and agribusinesses. Crop and conservation policies and social movements indirectly influence the local networks.

Chapters 5, 6, and 7 analyzed the roles of farmer innovators and key professionals in innovative networks during the initial phase of the



Figure 9.2. Constructing local knowledge of conservation tillage/cropping systems.



\*AES is the Agricultural Experiment Station

†CES is the Cooperative Extension Service

††NRCS is the National Resources and Conservation Service

§FSA is the Food Security Administration

social construction of the new or innovative tillage systems. The spread of conservation tillage systems, especially no-tillage, in Kentucky and Queensland was analyzed in chapter 8. The array of factors—policies, social movements, institutional developments, and biophysical factors—that have affected the spread of innovative tillage systems, beyond the initial networks of farmers to farmers in the United States generally are examined next.

*Prior Research on the Adoption of No-Tillage*

In spreading the seeds of no-tillage cropping in Kentucky, the institutional agents, especially of the Cooperative Extension Service (CES), played a prominent role. Although studies of the adoption of no-tillage in other states have not been designed to address the role of innovative networks, the findings of some of these studies do call attention to the importance of other farmers and institutional agents in the diffusion process.

In 1981, conservation tillage methods—no-till or minimum tillage—were used on 59 percent of Iowa's cropland.<sup>6</sup> That year 77 percent of a sample of Iowa farmers indicated that they had used "reduced-tillage" methods on one-half or more of their corn crop, and 50 percent used reduced-tillage on one-half of their soybean acreage year (Bultena et al. 1983). Although most of these farmers (40 percent) reportedly first learned about conservation tillage methods through the mass media (e.g., farm magazines and newspapers), the researchers report that friends and neighbors (33 percent) also figured prominently in the initial spread of these ideas. Moreover, in evaluating conservation tillage methods and deciding what to use, other farmers (neighbors, friends) (35 percent), followed by their own trials (24 percent), were the first sources of information mentioned most often. When it came to making a commitment to actually use reduced tillage practices, the decisive information for nearly three-fourths of the users was their own trials in constructing a workable tillage system.

Stronger evidence of the importance of institutional support—provision of credit, contacts with Soil Conservation Service (SCS), Agricultural Stabilization and Conservation Services (ASCS), and officers of local conservation districts, and an SCS-prepared conservation plan—in using conservation tillage comes from another study of farmers in three Iowa watersheds (Korsching 1984). The use of conservation tillage as measured by the amount of surface residue retained was significantly related to each of the three indicators of institutional support, but most strongly with the extent of contacts with conservation agency personnel.

Confirmation of the significance of these institutional sources in Iowa farmers' conservation behavior was obtained by a subsequent study of grain farmers in sixteen southwestern Iowa counties where the countryside is hilly to rolling, and the erosion hazard is severe (Korsching and Hoban 1990). For the practice of conservation techniques generally, information from a wide range of institutional and media sources was important. But, when it came to specific tillage systems, these farmers regarded the information obtained from institutional sources as partic-

ularly important. For instance, information obtained through the SCS and Soil Conservation District networks was notably important for the practice of no-till, ridge-till, or conservation tillage. Information obtained from farm magazines also contributed importantly to their practice of conservation tillage, but other farmers were not mentioned as important contributors to their practice of particular tillage systems.

The role of other farmers as information sources, however, is highlighted in a study of no-till users in the Palouse region (Carlson and Dillman 1986). For these wheat growers, the SCS and "another farmer" were the most frequently mentioned sources of positive influence. No-till users were also much more likely than nonusers to have traveled to see a no-till demonstration or talked with someone about no-till outside the Palouse. It is notable too that nonusers cite other farmers as the most important influence on their attitudes about no-tillage.

Most closely related to the studies of no-tillage in Kentucky are studies of 203 no-till innovators in Illinois in 1984 (van Es et al. 1986; Makowski et al. 1990). The studies provide insight into the roles of different information sources as well as to economic, policy, and agroecological incentives to adopting no-tillage. Farms in the southern part of the state occupy more rolling to hilly land and tend to be smaller than those in the northern half. Farmers in southern Illinois began constructing no-till systems almost as quickly as those in Christian County, Kentucky, and again the original stimulus was George McKibben's no-till experiments at Dixon Springs. In southern Illinois, the media, the Extension Service, and other farmers also figured prominently in getting out the word about no-tillage. Farmers in northern Illinois, however, initially learned about no-tillage somewhat differently—mainly through reports in the media, the SCS agents, and other farmers.

While most Illinois innovators searched for information about no-till for several years before trying it,<sup>7</sup> contacts (networks) with other farmers and institutional agents provided the best source of information about no-till, especially in the southern region. In this region where no-till began first, farmers felt that George McKibben (19 percent), the Extension Service (19 percent), and other farmers (30 percent) were the best sources of no-till information. In the north, the SCS (27 percent) and other farmers (20 percent) figured prominently as best sources, although the media (28 percent) were most often regarded as the single best source.

It is apparent that farmer networks were more active agents of no-till innovation in Kentucky and southern Illinois than in northern Illinois and Iowa. In the former locations, the CES figured prominently in the initial spread of no-tillage and encouraged networking as an instrument

of information diffusion. Similarly, in the Palouse, organizations of producers were instrumental from the beginning of the STEEP program of conservation tillage research and adoption (Oldenstadt et al. 1982). In Iowa, the CES specialists for many years were ambivalent at best about the prospects for no-till cropping (Rogers 1983), and CES was evidently quite inactive in promoting no-tillage in northern Illinois as well. In the more northerly areas, therefore, the advocacy of no-tillage was left to SCS agents who tended to operate on a case-by-case basis (i.e., one-on-one with interested farmers), rather than attempting to encourage establishment of networks of innovative farmers.

These studies broaden and strengthen the conclusion from Kentucky and Queensland that networks of institutional agents and farmers, whether one-on-one or in innovative groups, were the key mechanism in the spread of no-tillage systems. But, the advocacy of conservation tillage did not occur in a vacuum. The promotional effort was successful because, within particular policy and market contexts, farmers were able to construct tillage systems that were workable and profitable as well as resource saving. For southern Illinois farmers, no-till was a notably profitable alternative because the labor and time saving, coupled with a favorable climate and growing season, made double cropping as well as farm expansion profitable alternatives, as was the case in Kentucky. For northern Illinois farmers, double cropping was less viable, and the possibility of increased profits turned on relative economic costs and/or the desire to enlarge farm size. Northern farm operators were notably slower to adopt no-till, and, when they did adopt, they more often did so primarily to protect their soils from erosion or because policy change increased the economic incentives. The episodic pattern of growth in no-tillage reflects the varying impact of these institutional and contextual factors.

## The Takeoff Period

### *Forces*

Farmers in other states, as in Kentucky, were attracted to no-tillage by the relative benefits of the new system. Through 1971, these advantages (or benefits) were realized in the context of socioeconomic forces that since the 1950s had stimulated farmers to expand grain growing. Fueled by growing worldwide demand and rising exports, demand for wheat, corn, and soybeans continued to grow (Meekhof 1979; Mayer 1986). Rising prices<sup>8</sup> gave farmers an incentive to increase production either by removing land from conservation reserve, by increasing inputs, or by becoming more efficient. But, from 1961 to 1972, farmers in the United

States generally preferred keeping erodible land in conservation reserve for which they received government payments.<sup>9</sup> To meet higher production targets on the same land base, therefore, farmers increased inputs, causing input prices to rise. The cost/price squeeze pressured farmers to increase efficiencies, and throughout this period productivity rose dramatically (Schertz 1979b).

In 1973, the economic situation changed dramatically. Soviet Russia entered the grain market for the first time, causing both a substantial decline in U.S. grain reserves and a substantial rise in grain prices. The index of grain and feed exports, which was 100.2 during 1966–70, rose to 184.0 in 1976 (Meekhof 1979). In a widely heralded speech, Secretary of Agriculture Earl Butz called upon farmers to “plant fence row to fence row” to meet the rising world demand for grain. U.S. farmers responded by withdrawing land from conservation reserve<sup>10</sup> and increasing the acres of cultivation. In 1972, only 202.7 million acres had been planted in crops (see table 9.1), but in 1973 this jumped to 247.9 million acres and climbed to 284.2 million acres in 1976, an increase of 81.5 million acres (40 percent) in 4 years. Farmers continued to convert reserve land to cropland until 1981, when a peak of 317.3 million acres of crops were planted—57 percent more than a decade earlier. As pointed out in chapter 8, for example, innovative Christian County, Kentucky, farmers on average increased the amount of cropland farmed in the first 5 years by 50 percent.

This dramatic increase in cropland impacted cultivation practices in two ways. On the one hand, it provided a further incentive to develop or expand conservation tillage systems because much of the land brought into production was relatively erosion prone. This was especially true of much of the 50 million or so acres of land withdrawn from conservation reserve for cropping purposes. Between 1972 and 1976, the acreage under conservation tillage—minimum tillage or no-tillage—doubled, an increase of nearly 30 million acres. The percentage of cropland conservation tilled increased to 21.0, up 6.4 percent from 1972. Some of this growth, as we have seen, was in states that were achieving takeoff. Despite the progress in no-till and minimum tillage systems, however, more than 50 million acres were brought into crop production during this 4-year period under conventional tillage. Consequently, although conservation tillage systems continued to spread, the rate was not fast enough to adequately protect all of the newly developed acreage.

### Consolidation and Retrenchment

During the period of consolidation and retrenchment, no-till acreage, which had reached 7.5 million acres in 1976, declined slightly and

remained essentially stable at an average of 7.1 million acres through 1980. Meanwhile, however, the acreage minimum-tilled grew rapidly and in 1980 was 59 percent larger than in 1976. As a consequence, the decline in no-tillage did not adversely affect the continued growth in conservation tillage generally, which increased from 21 percent in 1976 to nearly 30 percent of the nation's cropland in 1980.

The national retrenchment in no-tillage during the late 1970s occurred despite the continuing spread of no-tillage as indicated by the four states in which the new system achieved takeoff. With strong support from institutional advocates, farmers in favorable cropping locations (e.g., Ohio, Tennessee, and Georgia) were constructing advantageous no-tillage systems as farmers in the core states had done several years earlier (Ladewig and Garibay 1983). Retrenchment in the core states, however, exceeded the growth at the periphery, resulting in a decline in the overall use of no-tillage.

Clearly, farmers in the core states were not continuing to utilize no-tillage to the same extent as previously.<sup>11</sup> But, for the most part innovative farmers did not give up conservation tillage entirely. Instead, they made increased use of minimum tillage systems, using conventional tillage when they felt it was necessary. Consequently, on the national level minimum tillage grew rapidly to 80.8 million acres in 1980, a 59 percent increase, whereas the acreage no-tilled and conventionally tilled both declined during this period.

### *Markets and Policies*

The continued expansion in cropland between 1976 and 1981 was spurred by continual increases in world demand for coarse grains (e.g., corn, soybeans, and wheat) and rising average prices for these commodities (see, for example, Webb 1981; USDA 1982). In addition to expanding the acreage under cultivation, farmers increased farm inputs, especially chemical inputs, and prices of these inputs increased substantially. Farmers faced a dilemma: Prices of gasoline and fuel oil more than doubled, and the cost of herbicides rose even more rapidly. This eroded the cost-saving advantage of no-tillage. For farmers who felt no-tillage was too risky or who had experienced difficulties, the decline in the cost-benefit structure did not encourage either innovation or expansion. For these farmers, the safest and least risky choice in expanding their cropland was to continue cultivation of the new lands conventionally.

Meanwhile, the principal governmental policies governing the operation of SCS, ACP, and other soil conservation agencies remained in place. Incentives to undertake investments in conservation cropping were weak, and farm conservation plans became outdated. The cost-

share policies of ACP continued to support practices fostering increased production at the expense of increased risk of soil erosion (Batie 1982, Heimlich 1986).

Public outrage, given voice by the Environmental Movement, at the apparent increased loss of soil resources, encouraged Congress to pass the Soil and Water Resources Conservation Act of 1977 and to specify rule changes governing cost-sharing arrangements in the Agriculture, Rural Development and Related Agencies Appropriation Act of 1979. States began revising legislation to provide subsidies to farmers adopting no-tillage. Although these policy changes resulted in increased information about the condition of soil resources, reduced support for production-increasing but soil-wasting practices, and increased the incentives to try no-tillage (Makowski et al. 1990), the impact of these policies occurred primarily in the following decade. In other words, the policies that encouraged withholding of erosion-prone land from production were ineffective in the changed economic situation of the mid- to late 1970s, and several years were required for farmers' responses to the 1977 policies to become widely apparent.

### *Cultural Warfare, Local Knowledge, and Global-Local Networks*

At the local level in most grain-producing areas, the plow was still the reigning instrument of cultivation despite the surge of interest in conservation tillage. Although the acreage conventionally tilled in 1980 was slowly declining, 70 percent of cropland was still managed under this system. In Iowa, plowing contests still were annual events with trophies awarded to the winners. The cultural battle for the farmer's allegiance to tillage systems was carried on, for example, in advertisements for plows and larger tractors and for new chemicals in farm papers. Often information relevant to conventional and conservation tillage systems, or stories trumpeting the advantages of the alternative systems, were published in succeeding if not the same issues. Responsible authorities recognized that farmers needed to use different tillage systems depending on *local conditions*. For example, in the December 1977, issue of *The Progressive Farmer* under the heading "Plowing—Are You Doing Too Much or Too Little?" Ken Bretches prefaced a discussion of different tillage systems by acknowledging that "[e]liminating all tillage except one pass . . . isn't for every farm. Differences in climate, soil types, weed pressures, crops, and chemical performance mean you have to fit your tillage system to conditions on your farm, not to someone else's model."<sup>12</sup> In other words, if you have experienced difficulty in attempting to change your tillage system, very likely you do not have the right soil, climate, crops, or weed regimes to use such radical systems successfully.

The difficulties in sustaining no-tillage systems encountered by farmers in Kentucky and southern Illinois illustrate the major difficulties. Satisfactory long-term chemical weed control and increased risks due to the greater management complexity of no-tillage were common problems encountered by the Kentucky innovators, whose cases are chronicled in chapter 6. But also, they had crop establishment problems in poorly drained fields, as well as nematode and rodent buildups under various cropping conditions. They quickly recognized that they had fewer options and greater risks of crop loss and/or increase costs with no-till than conventional tillage. The importance and heightened concern with weed and insect problems is reflected in the attention paid to such problems in the popular farm papers, which gave considerable space to new herbicides, sprayers, and management strategies in the spring and summer issues.<sup>13</sup>

For no-till innovators in erosion-prone areas of southern Iowa (Chibnik 1987) and southern Illinois (van Es et al. 1986) saving soil along with saving field (labor) time were the most salient reasons for trying to construct satisfactory no-till systems. Not surprisingly, because of the paramount soil conservation motives in trying no-tillage, most selected sloping fields as sites for the first trials. For southern Illinois farmers, selection of tillage system by field remained an important management principle because in 1980 only 24 percent of their acreage was no-tilled. Relatively "flat" and "poorly drained" fields were not no-tilled, which slowed the advance of no-till cropping in this area.

Initially, weed and grass control was the biggest problem faced by innovators in both states. The innovators had problems in obtaining satisfactory yields, which they attributed to greater prevalence of pests (insects and rodents) as well as poorer (slower) seedling emergence than with conventional tillage. Most recognized that continuous use of no-tillage required continuous "experimentation" and adaptive adjustments. With reference to no-tillage technology as used by Illinois innovators in the early 1980s, van Es et al. (1986, 60) conclude that "at the present stage of development, no-till is a rather complex practice without a standard procedure, requiring more in the way of management skills, experimentation and risks."

The other side of this problem is that, despite a decade or more of research and the stream of new knowledge about no-till cropping, which was beginning to flow from research laboratories, satisfactory technologies for dealing with these widely encountered management problems had not yet been found or made available to farmers. It would take another decade for farmers who had adapted to weed and pest constraints, for example, to decide to reverse course and to use better tech-



nologies to expand no-tillage. Confronted by difficult management problems, therefore, it is not surprising that some farmers stopped no-tilling, and others decided to use either minimum or conventional tillage to control weed, disease, and rodent problems. Their experiences, of course, quickly circulated in local networks, increasing the reluctance of farmers who had not tried no-till cropping to attempt construction of their own systems. Choi (1981) found, for example, that 36 percent of the farmers who had stopped no-tilling would not recommend the system to friends, compared to only 4 percent of the farmers who were still no-tilling. The potency of such local perspectives is indicated by the fact that both no-till “nonusers” and the “undecided” in the Northwest were as well linked to other farmer, as well as media, information sources as no-till users, and cited weed control difficulties and higher costs as principal factors in their present outlook (Carlson and Dillman 1986).

Technical and economic difficulties were not the only constraints slowing the advance of no-tillage. Older aged farmers and those with less education have generally had a more difficult time adopting new, complex systems of farming such as no-tillage (Swanson et al. 1986; Camboni and Napier 1994). In a period when grain producers expanded production by bringing land from conservation reserve into production, large producers often minimized environmental concerns and used conventional tillage. Where expansion of cropping involved rented acreage, conservation tillage generally—and no-tillage in particular—may have been constrained by tenure considerations (Ervin 1986).

### The Period of Gradual Expansion

As noted earlier, the nation’s no-tilled cropland more than doubled, both numerically and proportionately during the 1980s, reaching a takeoff level nationally of 5.1 percent in 1989 (see table 9.1). With 1989 as an exception, about one-fourth of the cropland nationally was also managed with mulch tillage systems during the 1980s. The proportionate increase in no-tillage came in the context of a 16 percent decline in total cropland, which occurred between 1984 and 1989. From a soil conservation standpoint, both of these trends were highly important. We argue that the two trends—increased no-tilling and decreased cropland—were primarily the result of different forces. The decline in total cropland was primarily due to farm economic and conservation policy changes occurring during the 1980s, especially the Food Security Act of 1985. However, the increase in no-till acreage was primarily due to expanding innovative systems in states that attained takeoff as a result

of the progress in research on no-till cropping and the strengthening of the institutional support for conservation tillage, especially no-tillage. The progress made in these respects—new technology and stronger advisory systems—began to alter significantly some of the important technical constraints to no-till cropping, which had earlier slowed its advance, with the result that no-tilling became a more practical and profitable system for innovators. Finally, the rising tide of environmental concern increased the incentive for farmers to engage in conservation activities.

### *Markets and Policies*

Early in the 1980s, the economic situation of grain growers in the United States changed dramatically. The strong export market for grain, which most experts predicted would continue to expand, suddenly became weak. The initial shock came in 1980 when President Carter embargoed grain exports to the Soviet Union because of the invasion of Afghanistan. The embargo was maintained for 16 months. More important in the decline of grain exports, however, was the reduced demand. This was due, first, to a worldwide recession beginning in 1982, causing demand to contract, and, second, to the strong U.S. dollar, which made U.S. grains more costly (Cochrane 1993; Evans and Price 1989).<sup>14</sup>

The reduced demand for coarse grains resulted in sharply falling grain prices. The Reagan administration encouraged farmers to reduce grain growing by making payments-in-kind (PIK) for reductions in the grain production base acreage. As land in the conservation reserve was excluded from the base acreage, conservation-minded farmers had little incentive to accept PIK for conservation purposes. Except for 1983, the overall effect on conservation of the PIK program thus was limited. Farmers sought to maintain production while controlling costs.

The interest in no-tillage increased in the early 1980s because of the cost-price squeeze and no-till's cost-saving aspects. The rise in the acres no-tilled between 1981 and 1985 reflects the increased interest.

Eight of the eleven states reaching takeoff during the 1980s (i.e., 5 percent or more of the acres no-tilled) reached this level between 1981 and 1985. In Illinois, which achieved takeoff in 1982, a 1982 study of no-till innovators (van Es et al. 1986) indicated that more than one-half expected to be no-tilling 50 percent or more of their land in 3 years. More than nine out of ten of the innovators believed that no-tillage was more effective than conventional tillage in reducing time in the field. In other words, the pressure to reduce costs and increase productivity generally increased the incentive for farmers to consider the no-till alternative (Crossen et al. 1986).

Enactment of the Food Security Act of 1985 changed the outlook for farmers in several ways. For grain growers in the short term, the most important features were the commodity support program and the CRP. To support grain grower incomes, the federal government replaced the PIK program with a policy of target commodity prices and deficiency payments. However, to reduce total cropland, protect erosion-prone land, provide wildlife habitat, and bolster farm income, the 1985 Food Security Act established a new CRP. Under CRP, a farmer could put erodible cropland under a 10-year contract with the USDA. In return, he received an annual rent, as well as a subsidy to establish grass and tree cover. The goal was "to retire 45 million acres of highly erodible cropland out of production" (Napier 1990, 4), and there were substantial penalties in loss of federal program benefits for violation of CRP contracts. A farmer could place corn, wheat, cotton, or soybean base acres in the CRP as well as eligible erodible land, which was not part of the base. The aims of CRP were linked to "sodbuster" and "swampbuster" programs of the Conservation Title that were designed to restrict the conversion of existing pasture or wetlands to cropland, unless it was done under an approved conservation plan.

The effect of the changed policy on cropland acreage was immediate. By 1988, about 23 million acres had been placed in the conservation reserve; 15 million acres of the total came from farmers' grain-base acres (Myers 1988).<sup>15</sup> As indicated in table 9.1, the tilled acreage declined nearly 33 million acres (10 percent) from 1985 to 1986 and fell farther in each of the next 2 years. This decline came primarily in the acres no-tilled and minimum-tilled, which makes evident that grain growers tended on balance to place erosion-prone cropland, which they had been protecting with conservation tillage practices, in the CRP while continuing to conventionally till the more productive, less erosion-prone land (Esseks and Kraft 1990). "Plant the best, and save the rest"<sup>16</sup> is not far from the management policy followed by many farmers. Other farmers perhaps saw in CRP an opportunity to obtain early retirement with a steady income (Swanson et al. 1990).

The slow advance of no-tillage cropping during the 1980s can not be attributed only to the impacts of shifting market prices and better governmental policy incentives. In their tillage decisions, farmers embrace a wider set of factors. Two increasingly important factors were the progressive strengthening of institutional and technical supports, which helped innovative-minded farmers construct new tillage systems, overcome many environmental constraints, and become more effective practitioners. A third was farmers' heightened environmental concerns, which the widening environmental movement strengthened, increasing their readiness to undertake conservation activities.

*Strengthening the Institutional Base: Research and Technology*

At the beginning of the 1960s, research on tillage and plant relationships did not have a high priority. The locations conducting this kind of research could be enumerated on one hand (van Es and Notier 1988). Of the 1,313 USDA and state agricultural experiment station scientists "conducting research on conservation and development of soil, water, and forest resources" in 1966, fewer than one in six was "studying soil structure and soil, plant, water, and nutrient relationships" (Bertrand 1967, 133). Although research evidence of the efficacy of various new tillage methods gradually mounted in the 1960s (Phillips and Young 1973), it did little more than demonstrate that a crop (e.g., corn) could be grown successfully under some kinds of limited, or no-tillage, methods in particular research locations. Agricultural scientists lacked understanding of many tillage system-plant relations. It is not surprising, therefore, that professional workers lacked the ability to answer many of the questions asked by troubled farmers and thus were less than highly effective as farm advisors. Unable to explain why mulch tillage gave good results in some places but not in others, farm advisors were primarily limited to pointing to farmers who were no-tilling successfully and to saying: "Why don't you try it?"

But, the successes of innovative farmers stimulated research administrators to expand research on the problems encountered. Farmers' increasing use of chemicals to control weeds and insects as well as to increase crop yields stimulated both the public and private sectors to dramatically increase research and technology expenditures (Huffman and Evenson 1993, table 3.12). Research expenditures, which in 1984 dollars were only \$99.4 million in 1960, increased to \$300.4 million in 1970, \$520.4 million in 1980, and reached \$637.0 million in 1984, more than a sixfold increase. The increase in the relative importance of research relevant to conservation tillage was equally dramatic. In 1960, the expenditures for weeds, insects, and plant nutrition represented only 4.5 percent of the total public and private sector expenditures for agriculture, but this increased to 26.1 percent of the total expenditures in 1984.

Research on conservation tillage greatly expanded at land-grant universities and the Agricultural Research Service, USDA. Between 1969 and 1984, funding in constant dollars for research on soil-related problems increased by 80 percent.<sup>17</sup> At the same time, public monies supporting research in the general category of "structures and inputs," which includes research on tillage machines and agricultural chemicals, increased by 97 percent. Research support for "management"-related

research on corn tripled proportionately between 1969 and 1984 and quadrupled for similar research on soybeans (Huffman and Evenson 1993). Meanwhile, the proportion of research expenditures for “postharvest”-related research on soils went from zero to 8.4 percent. Research information on plant response to various tillage methods on different types of soils, soil chemistry and moisture under different tillage regimes, weed biology and control, pests and pest management, machinery and energy use, and the like expanded rapidly. Studies of conservation tillage with different crops and cropping systems also expanded.

The result of the rapidly increased research investment was that, by the 1980s, significant advances were regularly being made in the knowledge base for conservation cropping. Scientific papers and conference reports on conservation tillage research findings, which appeared annually in the 1970s, in the 1980s became texts on limited and no-tillage systems (e.g., D'Itri [1985], Phillips and Phillips [1984], Sprague and Triplett [1986], and Wiese [1985]). The codification of research knowledge both expanded the available knowledge base and aided the training of professional workers.

Not the least important to the slow advance of conservation tillage during the 1980s, especially no-tillage, was the continual improvement in the supporting technologies of weed control and mulch planting. The markets for better chemical herbicides and trash planters, of course, expanded along with the progressive expansion of conservation tillage acreage. Chemical companies and machinery manufacturers responded to these expanding markets by aggressively expanding research and development of new products. The expansion in new technology is reflected in the numbers of patents issued by the U.S. Patent Office following World War II. Inventive activity (patents granted) for plows and cultivators during the 1960s fell almost 30 percent from the 1950–59 level as farmers turned away from conventional tillage with these implements to reduced tillage methods (Huffman and Evenson 1993, table 5.3). Patent activity in this area recovered moderately during the 1970s with the development of newer, less aggressive tillage implements, but did not reach its former level. Meanwhile, compared to the 1950s, the level of inventive activities for “planters and drills” rose 30 percent for each of the following two decades, and more than 200 percent each decade for new technologies in the area of “fertilizer plant husbandry.”

Farmers interested in conservation tillage not only began to have a wider range of better technology from which to choose in constructing their tillage and cropping systems, they could enlist the assistance of an

increasing army of company representatives in learning the new technical skills (Wolf 1995). In other words, the more the markets for chemical herbicides and trash planters grew and expanded into new areas, the more aggressive companies became in helping prospective customers become familiar with their benefits and learn how to use the products successfully.

### *Strengthened Institutional Support: The Advisory Services*

Although chemical companies and their field representatives provide extensive information and advice in the chemical control of weeds, primary responsibility for advising farmers in constructing conservation tillage systems on their farms is vested in SCS and CES field officers. Despite the enthusiasm for conservation tillage methods of some SCS and CES officers and administrators in core states, most advisors initially doubted its value, or practicality. This posture is hardly surprising as nearly all professional workers had been trained in the pre-no-till era and well knew that one had to bury surface residue, stir the soil, plow down fertilizer, and create a fine seedbed. Moreover, most SCS field officers had specialized in agricultural engineering, had limited training in agronomy or agricultural economics, and doubted that advising farmers on "cultural" methods was their responsibility. Even as evidence favoring conservation tillage methods mounted, the messages farmers received from most professional advisors about the new tillage systems were often conflicting and unconvincing (Behn 1984). Shirley Phillips, who was trained in agricultural economics as well as agronomy, expressed a common professional experience this way: "I spent half my career telling people how to prepare seedbeds for grain crops and the equivalent in backing off [from those ideas] and [in getting] into minimum tillage" (Phillips 1992).

Even after innovative farmers in many areas had begun the successful practice of conservation tillage and cropping and research had substantially broadened the base of scientific knowledge, SCS and many CES administrators were cautious to a fault in their endorsement of these revolutionary systems. R.M. Davis, SCS Administrator, USDA, writing about soil conservation in the *Journal of Soil and Water Conservation's* 1977 regional review of conservation tillage in the United States and Canada, felt compelled to note that, despite the possibility of substantially reducing soil losses with surface residue mulches, farmers would not accept the lower crop yields that commonly occurred, and the many unanswered questions provided no compelling basis for SCS to "abandon other excellent conservation systems and go overboard on conservation tillage" (Davis 1977, 6).<sup>18</sup> This hesitant institutional posture character-

ized the prevailing perspective of professional field staffs, most of whom felt neither competent nor responsible for advising farm clients on conservation tillage systems. Under such circumstances, only the most self-confident and least risk-averse farm entrepreneurs had the courage to invest time and money in such radical tillage systems.

Six years later, however, another SCS administrator was ready to propose a quite different, although still cautious, institutional policy on conservation tillage. Announcing in the *Journal of Soil and Water Conservation* that "the time has come for conservation tillage," Peter C. Myers (1983), chief of SCS, USDA, listed seven factors supporting this position, including the acknowledged soil- and labor-saving benefits of conservation tillage, the advances in weed control, and, not in the least important, the pushes by both the congressional and the executive branches of government for greater research effort to resolve unanswered questions as well as increased promotion of conservation tillage in critical erosion areas. In thus accepting responsibility for leading SCS into the conservation tillage era, Myers recognized there were important institutional hurdles still to be overcome. One was the reluctance, even after several decades of the successful utilization of conservation tillage systems by farmers, of some scientists and "soil conservationists and extension specialists . . . to endorse or encourage conservation tillage" (Myers 1983, 136). But, he argued that it was unnecessary to have all questions answered before becoming "enthusiastic advocates" of conservation tillage. SCS field officers responded to this message and soon became enthusiastic promoters of no-till cropping in the Midwest (van Es and Sofranko 1988).

In many states, however, the conservation tillage campaign was hampered by differences in CES and SCS field officers' views of the nature and scope of the associated tillage problems, especially with no-tillage (van Es and Sofranko 1988), and the agencies still contended over the scope and coordination of their respective responsibilities. Recognizing that the extension effort was hampered by interagency competition, Myers called for an end to the "turf battles" between CES and SCS. It would take another act of Congress, the 1985 Farm Bill, however, to largely overcome these institutional hurdles.

Meanwhile, the institutional base of the conservation tillage revolution was strengthened by other developments. In 1982, the *Conservation Tillage Information Center* (CTIC, now the Conservation Technology Information Center) was established under a charter of the National Association of Conservation Districts. With public and private funding, CTIC began sponsoring conferences (e.g., crop and nutrient management) and providing a wide range of informational services to members. One



of its important services is the annual collection and compilation of tillage data. This center, specialized sources (such as the *No-Till Farmer*), and popular farm magazines quickly began to provide the latest research findings and technical practice to interested professional advisors and farmers.

It seems evident that the progress in research understanding of the basic chemical and biological processes underlying the new tillage systems, improvements in technology, and the strengthening of the advisory systems helped innovators overcome many practical problems with their new systems and bolstered the slow advance of conservation tillage systems during the 1980s.

### *Cultural Movements and Tillage Practice*

Farmers have not been unmindful of the arguments of soil conservationists and environmental activists that the erosion of soil was wasting valuable resources and that conventional tillage was a major contributor. Most have long recognized soil erosion as an important agricultural problem (Christenson and Norris 1983), albeit on someone else's property (Nowak 1983). On their own farms, most farmers felt they were responsible stewards within limits of the perceived need and their ability to carry out conservation practices (Napier and Forster 1982; Molnar and Duffy 1988). This is not to say that soil conservation was the foremost goal of most farmers or that their perceptions of their erosion problems matched that of conservation experts. For example, in southern Illinois where soil erosion was recognized early as a major problem, only one out of seven farmers in the recession years of 1986–87 ranked soil-erosion control as even the third most important farm goal, far below financial growth, survival, and rural life style (Kraft et al. 1989).

The elevation of erosion control in farmers' ranking of important factors has been complicated by perceptual failures and conflicting beliefs. Not only have farmers typically failed to recognize the extent of erosion caused by their farming operations, many have protested that erosion-control measures were not needed even when the estimated erosion was three times the allowable benchmark of 5 tons per acre (Steiner 1990). The attitude of resource exploitation, moreover, continued to resonate with many farmers (Salamon 1992).

But, farmers' attitudes are influenced by events and by their involvement in an expanding public arena. Although all of the conservation tillage innovators studied herein started out with some level of concern with erosion, in most cases this concern was made salient by an event in which they were involved that particularly dramatized the resource cost of conventional tillage. Coupled with the conviction that the economics



of farming gave them little choice but to continue, even expand, cropping, the impact of this heightened environmental awareness invariably impelled them to change tillage practices. Moreover, in Illinois, for example, concern with soil conservation was an important factor, among others, in farmers' choices of tillage practices, especially no-tillage, despite its relatively low importance as an overall farm goal (van Es et al. 1986).<sup>19</sup>

The environmental movement in America impacted farmers' attitudes, even though during the 1970s farmers seemed slow to adopt the environmental perspective advocated by movement activists (Buttel and Flinn 1974). Although the level of environmental concern among persons with a farm background has been consistently lower than for urban groups (Jones and Dunlap 1992), in many respects their environmental attitudes differed little from the public in general (Buttel 1987; Lowe and Pinhey 1982; Arcury and Christenson 1993). It is apparent that, even though the concern of farmers about the environment has been lower than for other residential groups, the gap has never been very large, and the level or degree of farmers' concerns has risen and declined over recent decades in step with that of the general public.<sup>20</sup> Notably, public concern about the quality of the environment and the need for public action rose substantially during the 1980s, and farmers' concerns rose along with those of the public at large (Dunlap 1992; Jones and Dunlap 1992).

Studies of Ohio farmers' awareness that agriculture contributed to pollution was an important, although not the most important, factor in their acceptance of the conservation compliance provisions of the 1985 Farm Bill (Napier and Napier 1991). Moreover, the coupling of concern that soil erosion damaged the environment with the existing concern that it adversely affected future productivity simply added weight to farmers' decisions to use soil-conserving practices (Carlson et al. 1994; Camboni and Napier 1994).

### The Rapid Expansion

Between 1990 and 1998, cropland acreage in the United States managed under no-tillage and ridge-tillage systems tripled, equaling one-sixth of the total cropland. As noted earlier, this remarkable increase in use of these systems occurred both in states that had been early leaders in constructing no-tillage systems, such as Kentucky and Maryland, as well as in several outlying states, such as Colorado and North Dakota. In both types of locations, substantial acreages were being no-tilled, or ridge-tilled, for the first time. In 1998, for the first time the proportion of U.S.

cropland no-tilled and ridge-tilled equaled the proportion mulch tilled, and crops on two of every five acres were produced by one or the other tillage system.

The pace or speed of the increase in use of no-tillage and related conservation tillage systems during the 1990s rivals the pace of development during the initial takeoff over two decades ago. How can this second takeoff be explained? On the one hand, it seems unlikely that the rapid spread in no-tillage was due to a sudden increase in the numbers of farmers who had recently heard about no-till cropping. More likely, the rapid expansion was primarily due to farmers who had known about no-tillage for some time, but only recently had decided to start using the system extensively. What could have prompted so many farmers to undertake so radical a step on such a scale?

One important factor is the continued strengthening of the research system through the establishment of new institutions (e.g., National Soil Tilth Laboratory), as well as the greater allocation of research resources to issues of conservation tillage. This has generated a continual increase in research knowledge and conservation tillage technology. Continued progress in research has more clearly identified the relationship between tillage and soil and water quality for crop performance and sustainable agriculture (Carter 1994b). In particular, understanding of the complexities of tillage requirements as related to soil type, interactions of soil and climate, and the array of biological constraints have increased. The improvement of knowledge helps farm advisors and farmers to make better decisions as to the most effective tillage systems. No-tillage systems have especially benefitted from the continual improvements in related technologies.

In a wide-ranging discussion of agricultural technology and conservation tillage, Allmaras et al. (1998) identify several improvements in machinery that have facilitated conservation cropping. These include chisel planters, which combine tilling, planting, and fertilizing in a single operation; heavier seeders to provide better soil and residue penetration and sweepers to clear residue from the rows thereby permitting faster soil warming; and modifications to improve fertilizer placement. Significant advances have been made in weed management and control with the shift "from inorganic to organic herbicides, nonselective to selective herbicides . . . single herbicides to mixtures and even multiple applications" (Allmaras et al. 1998, 125). These technical changes, however, become most effective when made part of management strategies that make use of improved knowledge of weed ecology, biocontrol of weeds, herbicide-tolerant crops, and lower rate and more precise, variable rate, application of herbicides.

Plant disease control has been critical to the acceptance of conservation tillage systems because surface residues provide food and "housing" for the reproduction of most plant pathogens. Tillage systems that plow down, or bury deeply, infested plant residue reduce the incidence of such pathogens. Although biological control of root and crown diseases of small grains can be obtained by carefully managing crop sequence, fertilization, cultivar selection, infested residue, residue decomposition rates, and tillage practice (Allmaras et al. 1998), this system requires a manager with a high level of knowledge and skill in plant pathology. Selection of disease-resistant cultivars is the surest control of most foliar diseases that otherwise require use of short crop rotations, burial of infested residues, or fungicides.

The slow advance in tillage technology and management is a contributing factor, for example, in the expansion of no-tillage in most regions. In the corn belt, many farmers had for years shunned no-tillage systems because of poor crop performance due to cooler soils, allelopathy and improper seed placement, and avoided ridge-till because of its difficulty. Research studies with modified, no-tillage, and strip tillage systems in several states, however, have shown that satisfactory crop performances could be consistently obtained (Griffith and Woltenhaupt 1994; Lal et al. 1994). The principal challenge is for farm managers to construct successful, sustainable tillage and cropping systems adapted to their particular soil and climatic conditions.

Successful adaptation of no-till cropping systems in favorable soil types have been important in the greater use of no-tillage systems in the central and northern plains (Allmaras et al. 1994). Although research had indicated that farmers in the southern (Epplin et al. 1983; Epplin et al. 1994) and central (Williams et al. 1987) plains states would have difficulty growing small-grain crops as profitably with no-tillage as conventional tillage, more recent studies (Williams et al. 1989; Lafond et al. 1994; Aase and Schaefer 1996) indicate that innovative farmers in the central and northern plains could no-till cereals profitably.

Improvements in the system of no-tillage cotton cropping have contributed to its wider utilization in the Southeast (Blevins et al. 1994).

A related factor is that as the quality of farm management has continued to improve, farms have become larger, are more heavily capitalized, and have greater resources with which to acquire new technology.<sup>21</sup> Although these factors in combination increase the gravitational pull of no-tillage systems, this pull does not provide a satisfactory explanation of the dramatic rise in no-till acreage in the early years of the 1990s. Such an increase can only be accounted for by a drastic change in the forces affecting farmers' tillage decisions.

There is little mystery about what brought a sea change in farmers' tillage decisions as the 1990s unfolded. The compliance provisions of the 1985 Farm Bill and the 1990 amendments dramatically altered the effective policy and institutional environment. Farmers who wanted governmental support payments had to begin implementing their farm conservation plans (FCPs) by 1995, and their plans often included provision for conservation tillage. The balance of factors favoring use of no-tillage systems has also been strengthened by the progressive change in the cultural climate favoring farmers acceptance of program requirements and changes in farming practice.

### *The Impact of the Conservation Title of the 1985 Farm Bill*

The 1985 Farm Bill separated farm family income support and conservation objectives and made continued governmental income support contingent on compliance with approved conservation practices (Napier 1990). Although farm income was supported through familiar target prices and Commodity Credit Corporation (CCC) loan rates, to receive this support farmers with highly erodible cropland had to have an approved farm conservation plan in place by 1990 and had to fully implement the plan by 1995. This was in addition to the "Sodbuster" provisions, which required farmers to implement an approved plan when converting such land to cropland if they desired to receive governmental payment support. The 1990 Food, Agriculture, Conservation, and Trade Act (FACTA) continued the cross-compliance provisions of the 1985 Food Security Act (FSA), increased the attention to water quality and wetlands, and authorized the Secretary of Agriculture both to extend CRP contracts, which were scheduled to begin expiring in 1995, and to enroll additional acres in CRP contracts. The 1996 Farm Bill extended both the CRP program and the cross-compliance requirement for cropping highly erodible land, although the flexibility of the compliance was increased. It established an Environmental Quality Incentives Program (EQUIP), which combines the functions of the Agricultural Conservation Program, Water Quality Incentives Program, Great Plains Conservation Program, and the Colorado River Basin Salinity Control Program. EQUIP is targeted to high-conservation priority areas and provides cost-share, incentive payments, and technical assistance to producers with approved 5- to ten-year contracts.

These provisions of the 1985 Farm Bill impacted the operations of federal agencies and farmers' use of conservation tillage systems during the 1990s in three important ways. One is that "the obligation to make highly erodible land and wetland determinations and to help farmers with conservation plans caused SCS to put people and resources where

they were most needed" (Helms 1990). That is, the trend in targeting of SCS people and resources, which had been underway since the late 1970s, was reinforced. It is fortunate that this was so because of the very heavy workload that befell field officers in classifying lands, developing FCPs, and certifying compliance.

The obligation of SCS field officers to prepare and approve FCPs had the important effect of forcing field officers to bring economic analysis into farm conservation planning to a degree that they had heretofore avoided (Helms 1990). Out of necessity, field officers became more familiar with the economic as well as the conservation advantages of no-tillage and minimum tillage systems. This contributed to placing greater emphasis on no-tillage or minimum tillage system recommendations in FCPs. Not incidentally, this put officers of all federal agencies concerned with soil conservation—SCS, ASCS, and CES—on the same page so far as the advice and counsel each agency should be giving to farmers. As a result, the activities of governmental agencies became more complementary and mutually supportive (Hoban 1990; Nowak and Schnepf 1989; Johnsrud 1988).

Finally, the cross-compliance provisions of the conservation title had several obvious impacts on farmers. Compliance requirements increased farmers' motivation to seek SCS advisory assistance in conservation planning and implementation. In doing so, farmers gained authoritative information about erosion risks, which they may have downplayed previously (Napier and Forster 1982; Lovejoy and Napier 1990), thereby in some degree becoming more motivated to undertake erosion-prevention practices. Moreover, they received information about costs and benefits of alternative conservation compliance strategies. For many, the net benefit of a no-tillage system thus became more obvious, especially to those desiring to retain government program benefits. The increased advisory activities coupled with the collective engagement of neighboring farmers in constructing no-tillage systems doubtless produced a sunburst of local networking in targeted areas and a substantial expansion of local knowledge of no-tillage or direct drilling.

The net result is that farmers accepted and have implemented the conservation provisions of their FCPs (Esseks and Kraft 1994).

### *Impact of the Environmental Movement*

Continuity of these governmental policies as well as farmer acceptance of their provisions has been strengthened by the continued evolution of the public debate about the relationship between agriculture and environmental quality (Swanson and Coughenour 1994; Zinn and Blodgett 1994). During the 1980s, this debate, often couched in terms of (large)

industrial vs. (small) family farming (Berry 1977, 1987), or “conventional” vs. “alternative” (ecological) farming (Beus and Dunlap 1990; Youngberg 1984), had become increasingly moralistic and strident.<sup>22</sup> The debate challenged the cultural mandate of most farmers. It raised troubling questions about how the icon of American agriculture—a family farm—should be defined. Were “specialized” farms operated by families, or those with large acreages, a menace to the environment, failing in their stewardship obligations and thereby social outcasts? Understandably, the majority of the farm community, which long had enjoyed widespread cultural approbation as servants of the common good, suddenly felt itself somewhat isolated and under attack by various environmental interest groups.

During the latter part of the 1980s, however, the debate about agriculture’s relationship to the environment began to shift to issues of sustainable agricultural practices and systems.<sup>23</sup> Although agricultural and environmental advocates have differed as to the meaning of sustainable agriculture as well as on the priorities for making agriculture sustainable, the protagonists have been drawn into a common arena. Whether or not a particular farming system was sustainable could be seen to depend on a complex of social, economic, and ecological factors. Most farming systems were on a continuum of sustainability, rather than at one extreme or the other. More importantly, issues of sustainable agriculture were couched in the science-based languages of agroecology and the environmental sciences. Sustainability became a goal toward which improvement could be made, rather than a matter of flawed character. This is an endeavor in which all environmentally aware and concerned farmers could engage. A consequence of diverse groups joining in common endeavor has been a decline in the moralistic aspect of the debate about the present generation’s use of resources needed by future generations (Buttel 1992). This transformation of the debate helped restore the moral standing of the farming community and its institutional allies.

As agricultural scientists and farmers began working together on making farming systems more sustainable, they began establishing a common language of discourse. One result, for example, is an increasing degree of agreement among scientists and farmers on a broad definition of soil health (Romig et al. 1995). This convergence in outlook coincides with an increasing volume of research on the impact of agricultural practices on indicators of environmental health and on ways of improving it. In this respect, the social justice concerns of the past decade have been transformed to technical issues of sustainable agricultural practices and systems.

No-tillage has occupied a controversial position in this debate. Although its acknowledged benefits undeniably improve the sustainability of cropping systems (Lal et al. 1990), some environmentalists and ecologists contend that the greater dependence on chemicals harms the environment, especially water quality (Bird et al. 1995). Although many issues have not been resolved (Logan 1990; Logan et al. 1987; Isensee and Sadeghi 1993; Fawcett et al. 1994; Day et al. 1999), the point to be emphasized here is *not* that the environmental effects of no-tillage are entirely benign, but rather that the public debate about sustainable agriculture has encouraged the support of research on chemical use in no-tillage and other conservation tillage systems and of better management practices for reducing its effects (e.g., Anderson and Lockeretz 1992; Fawcett et al. 1994; Unger and Vigil 1998). Moreover, the more that farmers listened to, or engaged in, the debate, the more they have attended to environmental issues when constructing and adapting their tillage systems or when implementing FCPs (Carlson et al. 1994; Lasley et al. 1990; Supalla et al. 1995).

The growing consciousness of farmers with issues of sustainable agriculture has also contributed to the greater acceptance of governmental intervention for conservation purposes in exchange for governmental support as provided by the 1985 Farm Bill (Esseks and Kraft 1991; Napier and Napier 1991; Padgitt and Lasley 1993). Of greater importance, perhaps, the interest in sustainable farming operations makes the costs of compliance with FCPs seem less burdensome, thereby bolstering voluntary compliance with approved farm plans. For example, a *Wallaces Farmer* poll in 1989 found that 67 percent of Iowa farmers supported the compliance provisions whereas only 11 percent disapproved.<sup>24</sup> Although compliance monitoring remains important to farmers' full compliance with FCPs (Esseks et al. 1997), such public support of compliance tends to reduce the need for monitoring both because of the willingness of individuals to comply and the public monitoring and reporting of non-compliance.

In 1997, and especially 1998, farmers' cropping and tillage decisions were impacted by the economic crisis in Asia, which reduced grain exports to the region and grain prices. The decline in farmers' cash flows, of course, made them more cost conscious, especially of farm input costs. On the one hand, the decline in wheat prices caused farmers to shift to soybeans and corn where environmentally possible. Fuel prices declined more rapidly than chemical costs, including herbicide costs. This encouraged farmers to substitute mechanical cultivation for chemical weed control, which adversely affects the utilization of no-tillage cropping.



## Summary and Conclusions

During the past half-century, conservation tillage and cropping systems have become the tillage systems of conventional choice by farmers in one-fifth of the states and in 1998 was used on three of every eight cropped acres nationwide. No-till cropping, the most soil- and moisture-conserving method, has taken off as a cropping system in thirty-seven of the fifty states and Puerto Rico. In 1998, one-sixth of the cropland in the United States was no-tilled or ridge-tilled, and an additional one-fifth was mulch tilled. The growth in no-till cropping during this period has not been steadily upward (e.g., as exemplified by a logistic curve). Instead, the pattern of growth in no-tillage has been marked by an initial takeoff in a core group of states, followed by several years of relative retrenchment and consolidation in the initial core areas, while in other states around the core no-till was taking off. This was followed by a period in the 1980s of slow growth in no-tillage nationally, then, most recently, by a period of rapid expansion during the 1990s. The rapid increase in farmers no-tilling has occurred both in the core states and in states at the periphery. It would not be surprising for some retrenchment to occur for this reason alone.

Because of the revolutionary nature of conservation tillage/cropping systems and the critical importance of both the farm biophysical environment and the farmer's managerial abilities in building a successful system, the essential factor in the spread of successful tillage systems has been the establishment of networks of resource support. The gathering, testing, and evaluation of information, the modification of implements—chemical as well as mechanical—and development of skills in their use invariably has required the efforts of farm advisors and the action-learning of innovative farmers in networks. In large part, these innovative networks have been established through the direct intervention of agents of the Cooperative Extension and/or the Natural Resource Conservation Services. In the early years, professional agents usually took the initiative in locating cooperative farmers and offering to provide necessary advisory support. They were successful where they offered advice on the experimental development of new tillage systems rather than attempting to promote a particular technique.

During and after the initial takeoff, conservation tillage agriculture, especially no-tillage, was sustained by the general mobilization of global research and development organizations in expanding understanding of conservation cropping and in developing new technologies to deal with the emerging problems. Without the successful effort to expand research knowledge and develop new machines and herbicides, growth



of the new agriculture may well have been confined to a few favorable areas and dedicated farmers.

With passage of the 1985 Farm Bill, however, the context in which both innovative networking and acceptance of conservation cropping substantially changed. It ushered in an era of agent-farmer cooperation in the planning and implementation of conservation cropping systems. However, the importance of networking for tillage system construction did not change and will be equally important in sustaining the new tillage system among farmers who have become innovators during the past decade.

The role of media in tillage system dissemination has been substantially different from that depicted by the traditional two-step model of innovation diffusion. Although the agency of a farm advisor has been critical to initiation of farmer innovation, the media, especially farm magazines, have been crucial in spreading the new culture of agriculture—*notions* and the benefits of the new tillage systems—which prepared farmers to seize opportunities to join innovative tillage networks when the institutional and socioeconomic context favored it (Bultena and Hoiberg 1986; Korsching and Hoban 1990). Through media, farmers became aware of successful tillage systems as well as of potential problems in constructing them. Through media, farmers became aware of environmental concerns of the American public and reshaped their own perspectives of the environment.

The media have played an important role too in making farmers aware of the changing context of farming. Farmers' perceptions of the net benefits, including saving soil and water quality, and risks associated with constructing and using conservation tillage and cropping systems depend on the relative importance at any given time of several major factors. Farmers' perceptions of net benefits and risks involve assessment of evolving weed and pest regimes, changes in conservation and crop support policies, environmental movements, the development of research knowledge, and market prices of farm commodities and farm inputs. The incentive to undertake the personal and financial investment in constructing a new tillage system is substantially affected by information about these factors obtained through media.

In the initial takeoff phase, the perceived opportunities to substantially increase farm income through expanding the acres planted and double-cropping wheat and soybeans while saving soil on sloping fields were the principal incentives driving the innovative construction of no-till and minimum tillage cropping. The principal constraints were effective management of chemical weed control and the acquisition and effective use of no-till planters. Problems in controlling particular types

of weeds (e.g., johnsongrass) rodents, and seedling emergence in poorly drained or cooler soils caused some early innovators to shift from complete to partial use of no-till and made others hesitate to try constructing their own no-tillage systems.

These difficulties caused a retrenchment in no-tillage in the core states even as farmers in other areas were developing innovative tillage systems. Research and the development of better herbicides and management techniques (e.g., ridge tillage and clean-row planting) gradually enabled farmers who were committed to conservation tillage systems to reduce constraints. Improved conservation tillage technology coupled with a stronger incentive structure created by changes in governmental conservation and crop support policies contributed to a slow expansion of no-till cropping during the 1980s. With an effective conservation no-till technology readily available, the incentives to no-till cropping increased substantially with implementation of the compliance provisions of the 1985 Farm Bill in 1990. Although the continuation of governmental crop support and the monitoring of compliance, or the threat of it, were most important to the rapid rise in no-till cropping during the 1990s, they were made possible and compliance was bolstered by two other factors. One was the effectiveness of Natural Resource Conservation Service (NRCS) agents in preparing farm conservation plans in a timely manner and of NRCS and CES agents in supporting innovative-minded farmers in constructing satisfactory no-tillage systems as required by their FCPs. Unfortunately, the role of advisory agents and networks of farmers in the remarkable rise of no-tillage during the 1990s has been a neglected area of research.

During the past two decades, increasing numbers of farmers have accepted, at least in part, the perspectives advanced by advocates of the environment and of sustainable farming. In consequence, the moral and ethical basis for farmers' construction of conservation cropping systems has broadened from mere stewardship of the land to the sustainability of farming systems and a broad concern for the environment. This broader ethical perspective bolsters evaluation of their tillage operations in terms of the perceived impact on water and endangered species of plants and animals as well as soil resources.

Seeing themselves as partners in sustainable farming has had several consequences for farmers engaged in mulch and no-tillage cropping. First, it provides a broader basis of moral legitimacy to management of the new conservation cropping systems. In this respect, it strengthens the farmers' mandate to view cropping as an organic part of the whole environment. Second, it bolsters the willingness of farmers to comply with the FCPs prepared by NCRS agents. Third, it strengthens the incen-

tive to continue use of conservation cropping systems regardless of governmental farm program benefit requirements.

In consequence of the rapid increase of conservation tillage generally, and no-tillage in particular, it has become the conventional system of agriculture in nine states and Puerto Rico. The tenets and practice of plow culture continue to retreat in nearly all areas. The conventionality of conservation cropping as a cultural force helps sustain the practice of conservation tillage systems when inevitable difficulties arise and as governmental program benefits are phased out.

## Notes

1. See *No-Till Farmer* (March 1973).
2. This was the first year that the *No-Till Farmer* conducted a survey of tillage systems used by farmers in each state. The estimates of "no-tilled," "minimum-tilled," and "conventionally tilled" acreage in each state were made by asking each state soil conservationist "to place all tillable acreage" into one of three categories using the following definitions:

No-tillage: Where only the intermediate seed zone is prepared. Up to 25% of surface area could be worked. Could be no-till, till-plant, chisel plant, rotary strip tillage, etc.

Minimum tillage: Limited tillage, but where the total field surface is still worked by tillage equipment.

Conventional tillage: Where 100% of the topsoil is mixed or inverted by plowing, power tiller or multiple discings. (Lessiter 1973)

3. The estimates of cropland treated with different tillage systems does not include "no-tilled" citrus crops in California and Florida or no-tilled pasture renovation (Lessiter 1973).

4. The ten states with 50 percent or more of cropland under conservation tillage in 1998 were Alaska, Delaware, Iowa, Kentucky, Maryland, Michigan, Missouri, Pennsylvania, Puerto Rico, and Tennessee (CTIC 1998).

5. The Caribbean region includes only Puerto Rico. The 1972 report for this area seems to have used a different basis than other states.

6. Calculated from data published by *No-Till Farmer* (March 1982).

7. The search ranged over farm papers and reports, chemical dealers, other no-till farmers, equipment dealers, farm talk, tours, demonstrations, and consultation with extension and soil conservation agents. On average, innovators reportedly consulted four of these sources over a two- to three-year period before trying no-till themselves.

8. In 1970, the index of prices received by farmers with prices in 1967 as the benchmark had climbed to 110 (Tweeten 1979, table 6.3)

9. "Cropland withheld from production from 1961 to 1972 averaged 54.6 million acres annually, ranging from a low of 37.6 million acres in 1971 to a high of 64.7 million acres in 1962" (Tweeten 1979, 163).

10. Cropland withheld from production dropped from 62.1 million acres in 1972 to 19.6 million acres in 1973 and 2.4 million in 1974 (Tweeten 1979, table 6.2).

11. In Christian County, Kentucky, for example, about one-third of the farmers who had tried using no-tillage prior to 1977 had stopped no-tilling, and most of these were not planning to use it in the next 3 years (Choi 1981). An equal proportion had reduced the acreage no-tilled.

12. *The Progressive Farmer* (Vol. 92, December 1977, p. 19).

13. *The Progressive Farmer* (TPF) and other farm papers in the spring and summer issues annually featured the latest information on chemical weed and insect treatments, application methods, and the like. For example, the January 1976 (pp. 19, 31) issue of *The Progressive Farmer* carried a story "Their Land Produces 150%" on Harry and Lawrence Young's three-crops-in-2-years system, which acknowledges that they "see weed control as the No. 1 problem that must be whipped for anyone considering no-tillage production," and indicates the chemical treatments the Youngs use. The May 1977 issue of *The Progressive Farmer* headlines "How to Lick Bad Weather Weed Problems," acknowledging that "[e]ven the best planned chemical weed control program occasionally falls victim to bad weather," and listing recommended ways of dealing with weather complications. In a pattern that was not exceptional, the January, March, May, and June 1979 issues of *The Progressive Farmer* carried articles on "What's the Best Tool for Incorporating Herbicides?" "Tackle Tough Soybean Weeds with Directed Spray," "Apply Your Herbicide at Pin-Point Rates," and "New Herbicide Rigs Make the Scene," respectively.

14. Cochrane (1993) also attributes the sharp decline in demand to (1) the developing debt problem in Third-world countries, which compelled them to reduce imports, (2) the relatively high support-price for grains and cotton, and (3) the expansion of export subsidies for agricultural products by the European Economic Community giving their commodities a favorable price advantage.

15. Through 1989, 34 million acres had been enrolled in the CRP "In the News," *Journal of Soil and Water Conservation* 45 (January–February 1990), p. 103.

16. The quotation is from Gersmehl et al. (1989, 417). The statement is consistent with findings of several studies indicating that CRP participants tended to be the most capital-intensive farmers (Bultena et al. 1990) and those most concerned with efficiency and profitability (Camboni et al. 1990).

17. In 1984 dollars, public funding of soil research in 1969 was \$46,503,000 compared to \$83,878,000 in 1984. Funds for research on "structures and inputs" increased from \$14,333,000 in 1969 to \$28,127,000 in 1984 (Huffman and Evenson 1993, table 4.5).

18. It should be noted that the researchers providing regional summaries of the state of the arts of conservation tillage in this publication ranged from cautiously optimistic to pessimistic about the future spread of these revolutionary tillage systems.

19. Pope et al. (1983, 372) found that "On most Iowa soils, conservation tillage . . . can control erosion with the least reduction in individual farm profits," and could increase net returns if yields do not decline. In the Alabama Sand

Mountain region, no-till corn was the most profitable production system and could be combined profitably with the acreage set-aside program of the 1985 Farm Bill to further conserve soil (Gillespie et al. 1989). In Kansas, the highest net returns on erodible land could be obtained "using reduced tillage and enrolling low-yielding, highly erodible land in the CRP" (Rowell et al. 1990; 185).

20. The consistency of residential-group trends in the environmental concern, as well as the absence of large, group-mean differences, is suggested by the consistency in the low positive correlations between environmental concern and current residence over time (Jones and Dunlap 1992).

21. For a summary of socioeconomic factors that have been proven by research to affect the use of conservation practices, see Camboni and Napier (1994).

22. The moralistic tone of the debate, stems in part from the confrontation of the "gospel . . . of the ecological world view" (Nash 1976, 227) with what might be called the gospel of the family farm and the independent yeoman (Dalecki and Coughenour 1992). Swanson (1993) has discussed the impact of this confrontation on the formation of soil conservation policies. In such debates, progress is often deferred until some middle ground can be found.

23. A sampling of the wide-ranging debate is provided in Edwards et al. (1990), Jackson et al. (1984), Bird et al. (1995), and SWCS Board (1995).

24. Monte Sesker, "How Farmers View Conservation Compliance," *Wallaces Farmer*, Vol. 114, No. 11, July 1989, p. 22.

# 10

## Planning Conservation Cropping: Implications for Research, Development, and Extension

*If “the fundamental history of civilization is the history of the soils,” we have reached a time now when civilization, as we know it—art and literature; music, poetry and philosophy; cathedrals, houses, farms, universities and theaters—will go towards a rapid destruction unless we ourselves awaken to retrieve the land.*

—Elyne Mitchell in Beemster (1999, 13).

In the United States and Australia, the revolution in the culture of agriculture at the farm level, as previously indicated, has included all sectors of the agricultural industry: governmental policies, markets, media, private and public research and development agencies, and private and public advisory agencies as well as farmers. As a result of changes in these sectors, not only is the culture of agricultural practice fundamentally changed, but the socioeconomic context of farming is also fundamentally different than it was a half-century ago. As Constant (1987) argued, any system of technology can be usefully considered to have three aspects: the system of applied science of the technology, the organizations that produce the products (tools) and services, and the community of practitioners. These three aspects are coequal parts of any new technical culture. In this view, the science, institutions, organizations, and agencies involved with conservation tillage and cropping are as much a part of it as are the farmers practicing new tillage and cropping patterns. We have also given considerable attention to a fourth component, namely, the governmental policies, markets, and socio-cultural movements, which Constant regards as part of the host culture. These factors, or forces, have significantly affected the innovation and spread of conservation cropping.

In this chapter, we focus primarily on two of these aspects: (1) public conservation policies and (2) the research and advisory services. The

episodic trend in the spread of conservation cropping in the United States and Australia raises a number of issues in this respect. First, from the vantage point of history, what can be said about the success or failure of public policies regarding the revolution in agriculture? What policies seem necessary for a sustainable conservation cropping culture? Second, with respect to the support for the construction and spread of conservation tillage and cropping, what did the research and advisory (extension) institutions do that had positive impacts? And, where did they fail in providing the necessary support? Nationally, the scope of these issues is too large to be dealt with adequately in a single chapter. We reduce the scope to more amenable size by focusing primarily on the effects of policies and institutional programs on conservation tillage and cropping in Kentucky and Queensland.

## Evolution of Public Policies and Advisory Programs

### *The Innovation Period*

In the United States, the 1950s and 1960s were the periods of the greatest innovative activity in conservation tillage and cropping at the farm level. It began with the innovation of stubble mulching in the plains states, and innovativeness carried over to no-tillage in Kentucky and the middle states a decade later. What policy initiatives contributed to these developments? There were several. One was the expansion in policy support for agricultural research. This was especially significant in the development of the soil conservation research laboratories where the role of stubble and soil surface textures in preventing wind erosion and aiding water infiltration was studied. This spread to studies of surface residues and water erosion. Research on managing soils for crops, cropping in crop residues, and managing chemical weed control were entirely different issues that required extensive research over several decades. Although the enormous significance for conservation tillage of this research effort cannot be denied, the vast bulk of the research, excepting studies in the soil-erosion laboratories, was an unintended consequence of public policy support for R&D to support the adjustment of American agriculture in the post-World War II period.

Soil conservation policies per se impacted farm-level innovation in conservation tillage primarily in four ways. The first, already noted, was in stimulating research on erosion control. Second, the water management projects of Soil Conservation Districts as well as the support of erosion-control practices by the Agricultural Conservation Program (ACP) (e.g., building ponds, drainage ditches, pasture and set-asides) had the effect of heightening farmers' concerns with the problem of soil

erosion. Both were of relatively minor significance so far as conservation tillage innovation. The third was of greater significance, although altogether unplanned. The Soil Bank program, which converted erodible cropland to grassland, had the perverse effect of increasing cattle numbers, lowering cattle prices, and increasing price incentives for farmers to raise commercial grain crops. The price incentive to raise crops provided strong motivation for erosion-concerned farmers to find alternatives to plow culture. Finally, the narrow focus of the Soil Conservation Service (SCS) on water management and erosion control both blinded and constrained agency officials in considering cropping and weed control technologies, which ultimately were the major areas of innovative development.

The incentive to raise crops, rather than to protect erosion-prone lands with grass and forage crops, was also strengthened by commodity parity-price policies, which reduced risks of price swings. With respect to the revolution in conservation tillage in the United States, therefore, the farm-level innovations triggering the revolution were largely unintended consequences of public agricultural and conservation policies. Being unintended and therefore unplanned outcomes of public policy, it is hardly surprising that the innovations in conservation tillage were largely ignored by soil conservation officials for two decades or more.

In Australia, the individual states under the Australian constitution have primary responsibility for soil conservation policy and programs. The spectacular dust bowl events of the 1930s in Australia as well as the United States created an awareness of the need for soil conservation. The attention attracted to soil erosion and large-scale salinization in western Australia spurred most Australian states to establish soil conservation agencies. Not until the Whitlam administration (1972–1975), however, did the Commonwealth government begin to engage the problem of soil conservation (Northrop 1999). A small sum of money was made available to study this national problem, resulting several years later in the landmark 1978 report, *Collaborative Study on Soil Conservation*. This was followed in 1983 by establishment of the National Soil Conservation Program (NSCP) by the Commonwealth Minister for Primary Industries. The objective of NSCP (1983–92) was to develop and implement national policies for the rehabilitation and sustainable use of the nation's soil and land resources.

The NSCP stimulated research and extension programs to strengthen the focus on soil conservation. It provides funds for state governments to initiate conservation studies and to help develop or adapt conservation technologies developed overseas, especially in the United States, to the needs of Australian farmers. The individual states, of course,



responded differently to the Commonwealth NSCP program depending on their particular research, extension, and teaching needs.

Due to the late entry of the Commonwealth government into the war on soil degradation, the farm-level innovation in conservation tillage and cropping in Queensland, as the analysis in earlier chapters indicated, was primarily impacted by policy initiatives of the Queensland government. Queensland administrations began to develop policy support for erosion control in the 1950s. It was under the broad authority of the Soil Conservation Act of 1961 and subsequent amendments that the Soil Conservation Authority (SCA) in 1971 acted to bring tillage implements from the United States for evaluation. This initiated tillage innovation in Queensland. As in the United States, a separate entity—the Soil Conservation Section, later the Soil Conservation Branch (SCB)—was authorized to plan and conduct soil conservation programs. Meanwhile, responsibility for extension support of crop production was vested in other agencies. This separation of responsibilities had pernicious consequences for conservation tillage innovation similar to those occurring in the United States. That is, although the SCB was comfortable in considering tillage methods, it required the cooperation of its complementary agency—the Agricultural Branch—to investigate implications for cropping. Similarly, the Agriculture Branch's mission excluded consideration of tillage methods for erosion control purposes. This “tunnel” policy perspective of narrowly focused agency missions constrained the consideration of the broader issues of conservation cropping, which the innovation of tillage cropping frames and systems required.

In the early 1970s, at the conservation tillage innovation stage, research policy and programs were focused primarily on crop and pasture development and soil typing. Research on stubble mulching, the effects of stubble mulching on water runoff and erosion on soils of the Downs, or on cropping with stubble mulch was non-existent. This lack of research data, of course, prompted the SCA to set up the Machinery Evaluation Committee (MECs) precisely to develop accurate data on the performance of chisel plows, rod weeders, blade plows, and stubble-mulch planters. The *Annual Report 1979* of the *Soil Conservation Authority (SCA) Queensland* called attention to the lack of research data on soil/climate relationships, which had prevented quantitative application of the Universal Soil Loss Equation (USLE) in assessing the effects of management practices on soil erosion, and noted that such studies had been initiated (SCA 1979). Significantly, conservation tillage and cropping innovation had occurred, without benefit of reliable research data, but rather on the basis of a general recognition, or notion, of the effects

of tillage practices on soil erosion. In the early 1980s, innovative farmers similarly began to substitute herbicides for cultivation in fallow weed control on the basis of observations of field studies. In some cases, the field studies resulted from the cooperation of chemical companies and SCB or Agricultural Branch officers, and in other cases from direct farmer-chemical company collaboration. The contribution of local agricultural research in the innovation phase of conservation tillage and cropping thus was minimal.

Meanwhile, a major storm produced erosion events in 1972–73, which tended to validate both the narrow focus on water management through engineering works and vesting responsibility for management with the SCB. Slowness of farmers in addressing soil erosion problems justified more direct governmental intervention. Under authority of the Soil Conservation Act, the Governor in Council declared eleven shires on the Darling Downs an Area of Erosion Hazard (AEH). This declaration provided for coordinated planning and implementation of water and erosion control works at farm and watershed levels on a mandatory basis. The SCB, under the authority of the Soil Conservation Authority, was empowered to initiate conservation planning on farms and in the AEH area. There were two mechanisms for implementing plans: (1) the preparation of project plans for areas (e.g., watersheds) requiring coordinated conservation measures and (2) the issuance of orders to landholders for development of farm soil conservation plans.

Once a farm plan of conservation works was developed and advertised for thirty days, during which objections could be raised, it became a "Notice," carrying the force of law. Thus, the plan of conservation works on the farm became a mandate. To carry out the mandated conservation measures, a farmer could obtain a subsidy of 50 percent of the cost of construction up to a maximum of A\$1,500 per property and/or could use up to A\$500 of the subsidy to acquire conservation equipment (e.g., a bulldozer). In addition, farmers could obtain low-interest bearing loans from the Agriculture Bank for up to 90 percent of the cost of erosion-control measures. A decade after declaration of the AEH, a survey indicated that 80 percent of the area farmers had a farm conservation plan, most of which had been developed during the past decade (Chamala et al. 1983). The effectiveness of this type of mandatory program in accomplishing its major purpose of constructing water control measures cannot be gainsaid (Coughenour and Chamala 1989).

### *The Retrenchment Period*

In the United States, state and Agricultural Research Service (ARS) research programs relating to conservation tillage and cropping continued

to expand rapidly during this period. Social scientists began to study the social and economic aspects of conservation tillage. Regional and national conservation tillage conferences reporting the results of research became annual events. Consequently, the conservation tillage frame continued to expand, providing technical solutions to problems encountered by early innovators as well as the basis for the continuing reconstruction of conservation tillage systems in new states.

Expansion of science knowledge in the conservation tillage frame progressively reshaped the technical and organizational culture of extension. The scope of the new tillage and cropping systems crossed normal disciplinary boundaries, requiring its advocates to broaden their expertise and/or operate in teams.

For the most part, however, benign neglect continued to characterize the United States soil conservation policy and program approach to conservation tillage and cropping during this period. Although SCS policy nationally failed to provide organizational support to strengthen and spread conservation tillage, states level SCS policies began to change (van Es et al. 1986), and increasing numbers of individual field officers began to recognize its potential soil-conserving benefits and to become advocates.

In Queensland, although the AEH program had largely succeeded in the engineering of water control measures, it was notably ineffective in attaining the broader objective of encouraging farmers to conserve soil through stubble mulching. Use of stubble mulching, although promoted, was not mandated. By 1982, only a small minority of farmers had all the equipment needed for the purpose, and an even smaller minority were using the equipment effectively to save stubble.

In part, the AEH program failed in its broader purpose, as the earlier analysis suggested, due to the concentration of financial and manpower resources on construction of water control measures. Only two or three field officers were actively promoting stubble mulching. Among farmers, the pervasive belief was that the erosion problem had been solved by the construction of contour banks and waterways. The AEH also failed politically because some farmers failed to complete conservation measures and, more importantly, because farmers in non-AEH areas of the state felt their soil-erosion problems were being ignored and that they were not receiving a "fair" share of benefits (Coughenour and Chamala 1989). For these reasons, the program was abandoned in 1986.

Although technical research information about conservation cropping was beginning to grow, SCB administrators in particular were becoming increasingly frustrated with the slow pace in the spread of stubble mulching. It seemed apparent that the Soil Conservation and

Agricultural Branches needed to develop a coordinated extension program to spread information about stubble mulching. Under the leadership of Tarek Kamel (SCB) and Peter Wylie (AB), a coordinated program was developed in 1981–82 for the Darling Downs region. The program aimed to develop material for press releases, information packages for use by extension officers, and to continue to support field officers by newsletters and advisory assistance. Nevertheless, struggles between the two agencies over the content and delivery of the information messages severely handicapped program accomplishment.

### *Slow-Growth Period*

From a policy and program standpoint in the United States, initiatives related to the Soil and Water Resource Conservation Act of 1977 (RCA) and related legislation, which came to fruition in the early 1980s, and the conservation provisions of the Food Security Act (FSA) of 1985 were the most significant developments during this period.<sup>1</sup> A legislative oversight directive in 1976 requested the USDA to produce evidence on the impact of its programs. The RCA process required USDA, among other things, “to evaluate annually program performance in achieving conservation objectives” (Batie 1982, 29). In consequence of these and related initiatives, the spotlight was turned on agency and program performance, thereby improving decision making; interagency cooperation in conservation programs was strengthened; ACP program support for practices that aided production more than conservation was ended; funding was increasingly targeted to areas of greatest need; and, alternative ways of increasing incentives to farmers for soil and water conservation were more widely debated.

In part a consequence of these initiatives and in part a result of increased public environmental concern focused on soil and water conservation, the conservation programs of the 1985 FSA not merely increased the momentum for changing the culture of agriculture but also established the basis through conservation compliance regulations for a second takeoff in the spread of conservation cropping in the 1990s. In addition to providing means of protecting highly erodible lands, establishment of the Conservation Reserve Program (CRP), along with Sodbuster, demonstrated public and governmental commitment to soil conservation. The complete implementation of an SCS-approved farm conservation plan (FCP) was made the institutional mechanism for permission to convert pasture or conservation reserve land to cropland. Moreover, farmers with highly erodible land who desired to receive benefits from federal price support or crop insurance programs had to have a FCP developed by 1990 and fully implemented by 1995.

Conservation tillage and cropping for areas in which economic as well as conservation benefits could be obtained were made key features of FCPs. This gave new impetus to SCS to consider soil resource development and use as well as resource conservation in farm plans. The similarity of SCS and CES objectives for farm management facilitated cooperation in providing advisory assistance. The development of an FCP, in itself, heightened the importance of conservation cropping; its implementation made this manifest.

Although the foregoing developments significantly strengthened the institutional and organizational aspects of the new culture of agriculture, the technical science base of conservation tillage was similarly being strengthened. The pool of science-related knowledge had grown to the point, for example, that agricultural scientists began publishing an increasing number of books on conservation tillage. This greatly strengthened the training programs for professional researchers and farm advisors.

In Queensland, by 1982 it had become obvious to DPI administrators that the spread of stubble mulching had stagnated and that the common fallow management practices of farmers were quickly destroying rather than saving stubble. Moreover, although satisfactory models of stubble mulching were available, the model systems were not being adopted by other farmers as traditional diffusion theory led one to expect. This situation contributed to a decision by the DPI to authorize the Soil Conservation and Agricultural Branches to study the management of the entire cropping system with special emphasis on the management of fallow. The study, under the leadership of University of Queensland-based social scientists (Chamala et al. 1983),<sup>2</sup> revealed that farmers believed soil erosion was more of a problem of the past than the present due to their construction of contour banks and waterways under AEH. Moreover, nearly all farmers felt they had to cultivate five or more times during long fallow periods to control weeds, a practice that quickly destroyed stubble. Most doubted that use of herbicides was economical and feared the extensive use of chemicals. In short, they were poorly informed about the need for conservation tillage and its benefits. Finally, although many SCB officers felt they lacked sufficient knowledge of stubble mulching to advise farmers, many Agriculture Branch officers doubted that the practice was economically profitable.

The study resulted in several initiatives. First, the SCB initiated hands-on training of field officers in stubble mulching technology and management. The increased competency empowered SCB officers to begin working with farmers in re-constructing conservation tillage systems. Second, a team of SCB officers and University Extension faculty<sup>3</sup> designed,

developed, and tested a "Conservation Cropping Information Package" including two videos, a conservation tillage pamphlet, and a user's guide for extension officers. The purpose was to provide an educational instrument to help close the information gap about conservation cropping. It was one of the tools used by SCB officers with adult learning groups to stimulate discussion and to develop innovative networks. The evaluation of extension strategies for conservation cropping peaked with a 1987 workshop to review and identify future strategies and to develop guidelines for selection of strategies (Marshall et al. 1988). Most successful of the techniques was the establishment of learning groups focused on farmer-identified conservation tillage and cropping problems (Begbie 1988). The network of shared conservation tillage experiences expanded considerably with establishment of the Conservation Farming Information Centre (now CFI Inc.) with its newsletters and annual conferences on conservation farming.

Meanwhile, two developments at the national level notably strengthened conservation cropping research and practice in Queensland. In the early 1990s, the changes in cropping and farming systems resulting from the adoption of chemical weed control and other new management practices increasingly aroused discussion by members of the new Australian Society of Agronomy (ASA). The Society decided to make reduced tillage the theme of its second annual conference, and S. H. Phillips from Kentucky was "invited to review tillage research in Australia and to present his findings to the conference" (Cornish and Pratley 1987, vi). Phillips' recommendation to publish a monograph on tillage in Australia resulted in the landmark publication *TILLAGE: New Directions in Australian Agriculture* (Cornish and Pratley 1987), which gave research and training programs an important boost.

State-initiated efforts to conduct conservation-related studies or to adapt conservation technologies developed overseas had expanded. By 1984, researchers from northern N.S.W. and Queensland were able to hold their first conference on no-tillage crop production (Martin and Felton 1984). Research also was bolstered by funding in 1983 from the National Soil Conservation Programs (NSCP). NSCP was established by the Commonwealth (Australian) Minister for Primary Industries in response to recommendations in the *Collaborative Study on Conservation*. The objective of NSCP (1983–92) was to develop and implement national policies for the rehabilitation and sustainable use of the nation's soil and land resources.

As one of its initiatives, NSCP sponsored a national study in 1984–5 of the involvement of local community leaders in District Soil Conservation Advisory Committees (Chamala and Maurer 1986). Similar

studies in the United States were also reviewed. The study found that the program impact of involving the local community in planning and implementing soil conservation projects was substantial. Moreover, both extension agency staff and local farmers strongly favored greater participation in such projects. As a result, NSCP changed its funding guidelines, specifically advertising for projects that involved the community in soil conservation. Pilot projects in four states were funded, one in Queensland's Lockyear Valley. The success of the pilot projects signaled a shift in the governmental approach to soil conservation from a traditional "transfer of technology" from experts to users to community-planned and -directed soil conservation programs with governmental support.

### *The 1990s Period*

In both Kentucky and Queensland, the culture of agriculture took on a substantially new face in this decade. On the research front, water quality problems associated with runoff from cropland became equally as important as issues of soil compaction, precision application of nutrients, and weed management methods. There was little reduction in the overall research effort to find solutions to problems of conservation tillage and cropping.

Implementation of the conservation provisions of successive Farm Bills from 1985 onward, however, had major impacts. The necessity of having an approved FCP energized both farmers and SCS agents in Kentucky, as it did elsewhere. The necessity of developing plans that took into account economic as well as conservation objectives tended to end the remaining conflict between agencies. As a result, farmers with highly erodible land now knew what was required for resource conservation on their farms, and the tillage data indicate that they have been following these plans.

In Australia, policy, agricultural research, and extension programs in the 1990s have been ruled by two policy themes: citizen, or client, involvement and sustainable agriculture and resource use. Governmental agencies have increasingly sought to engage interested parties in program planning and implementation, and those programs with an environmental orientation have elicited the ethic of sustainable resource use. The Land and Water Resources Research and Development Corporation (LWRRDC), for example, has spearheaded a movement to involve all interested parties (stakeholders) in their R&D planning and implementation.<sup>4</sup> R&D corporations for each agricultural commodity—dairy, meats, wool, cotton, and grains—have made the sustainable use of resources a research criterion in evaluating research proposals. Both



LWRRDC and the Grains Research and Development Corporation (GRDC) have a concern with research on conservation cropping.

The Horticulture R&D Corporation has pioneered in strengthening farmers' abilities to carry out on-farm research through training farmers to conduct their own experiments. The training module—"Do-Our-Own-Research" (DOOR)—developed by Hunter et al. (1996) for this purpose could be modified for use by farmers in research on conservation cropping problems. Similarly, the Meat and Livestock R&D (MLA) Corporation has started funding a new scheme called "Producer Initiated Research Development" in which several producers collaborating with researchers and extension workers can obtain MLA funding for a research project they have developed.

Although sustainable use of agricultural resources was a common theme running through many of the changes in Australian R&D programs during the 1990s, there is further need for investments in specific projects focusing on conservation cropping problems. At present, limited research in Queensland on these issues is carried on by the commodity research institutes of the DPI, such as the Wheat Research Institute and the Farming Systems Research Institute.

The national planning and operational frame for conservation programs changed substantially in 1989 with the policy statement—*Our Country Our Future*—by then Prime Minister Bob Hawke. The policy initiative, which was made in response to a joint submission by the National Farmers' Federation and the Australian Conservation Foundation, established a National Landcare Program (NLP) and launched a "decade of Landcare" (Lockie and Vanclay 1997). The program was promised A\$26 million each year, to achieve "sustainable land use through reducing land degradation and caring for natural resources . . . by the combined action of the community and the government" (NSW Landcare Working Party 1991, 1; quoted in Lockie and Vanclay 1997, 4). The program's key mechanism was establishment of local Landcare (i.e., environmental planning and implementation) groups. In this respect, it has been highly successful. Although the initial aim was to have organized 2,000 Landcare groups by 2000, by 1999 more than 4,500 groups had been formed, and the membership of these groups included more than one-third of all Australian farmers.

The Landcare program paved the way for a paradigm shift in the extension approach to delivery of services from a "transfer of technology" model to an interactive-group-advisory and technical assistance model. The shift in approach was designed to better address perceived deficiencies in management skills and business orientation of Queensland farmers. This effort gained momentum through a new

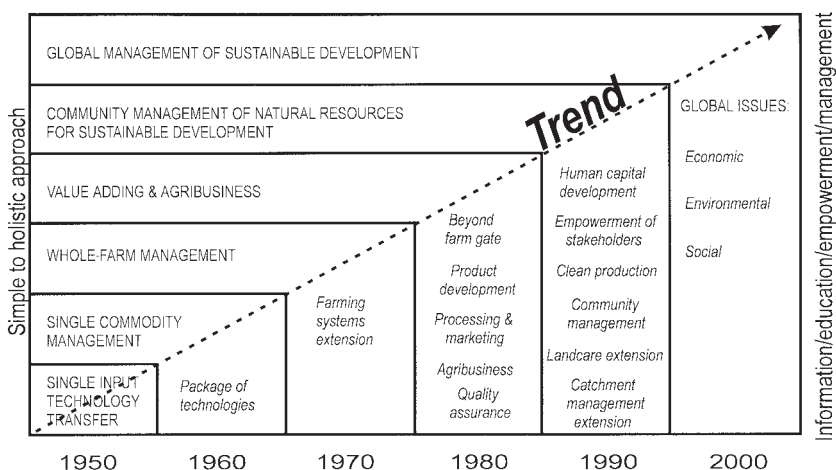


Commonwealth-sponsored program of Property Management Planning (PMP). Starting with the identification of personal objectives in the context of broader community goals, PMP sought to develop a total farm management process to improve profitability and sustainable resource use. Starting in 1993, the project has an estimated budget of A\$120 million spread over 7 years to 2001; individual states also have provided complementary funding. Landcare and PMP have achieved unprecedented success in creating conservation awareness and in implementing broad conservation objectives. However, the general farm management and community environmental improvement projects have rarely included, for example, improvement in on-farm weed or fallow stubble management. In this respect, the priority of conservation cropping has progressively receded.

### Changes in Agricultural Extension in Australia: A Summary

Although researchers studying underlying conservation tillage processes during the past half-century have become increasingly aware of agroecosystem relationships, the professional advisory (extension) services have progressively changed their approach to farmer clients from a technology transfer (i.e., “top-down”) approach to an approach emphasizing assistance in information resourcing and experimental learning. With reference specifically to Australian extension, Chamala (1999) has conceptualized the change as two dimensional (Fig. 10.1). On one dimen-

Figure 10.1. Changes in extension's approach to its clientele.



sion, there has been change in the principal content of the extension message from the provision of simple technical information through single product management, to whole-farm management, to value-adding agribusiness and agroecological issues on community and even global scales. On the other dimension, the aim of extension has shifted from training information, to education and then to the empowerment of individuals and finally collective management. Along the way, the change in extension served to facilitate agricultural development. But, the linkage of sustainable farm and catchment resource use with “community management of natural resources” and global environmental issues presents complex challenges. Extensions’ clientele and its role in helping these clientele to deal with these complex issues is still unclear.

### Challenges for the Continued Advance of Conservation Cropping

Analysis of the spread of conservation tillage and cropping in the United States has clearly indicated that the growth of the new culture has not been a smoothly upward curve since the innovative period during the 1950s and 1960s. Whether one looks at the overall spread of conservation cropping or more narrowly on the spread of no-tillage, growth has been episodic. The early enthusiasm of farmers and some of their supporters waned as the early innovators confronted new problems in weed control, plant emergence, and the like. Newly interested farmers were able to comprehend the “frame” of the new culture but had difficulties in constructing successful practices of reduced or no-tillage. To construct satisfactory practices, each farmer had to be committed to an extended period of action-learning of successful practices under different weather, soil, pest, and socioeconomic conditions. Use of herbicides, rotations, and new types of machinery, under varying weather, soil, and crop-residue conditions, to produce a profitable crop challenged the managerial abilities of all innovators.

Market forces affected the spread of conservation cropping in several ways. In the United States, good commodity prices provided incentives to expand conservation cropping on erodible lands whereas poor prices favored keeping such land in conservation reserve. Trends in relative prices for chemicals and machinery tilted the balance either toward, or away from, the substitution of chemical for mechanical weed control. In Australia, market prices and drought had devastating effects on conservation cropping methods and farming in general. Drought, although it reduced the need to control fallow weeds, also left little crop residue to protect fields. It compelled farmers to change their cropping and

farming systems, and, occasionally, their occupational commitments. As Roy Noller (1995) noted, the plans and dreams of many farmers turned to dust during 4 years of drought.

Public concerns with the environmental impacts of toxic chemicals affected the spread of conservation tillage in Australia in two ways. It heightened farmers' concern with possible harmful effects, often delaying the initial attempts to substitute herbicides for cultivation in weed control, and it made those convinced of the necessity of chemical weed control more cautious and careful in the application of chemicals. The hesitant pace of the reconstruction of satisfactory conservation tillage cropping systems has been compounded by the emergence of herbicide-tolerant weeds, crop diseases, and rat and mouse plagues.

The problems that continue to constrain successful application of conservation tillage and cropping highlight the importance of sustaining public policies as well as programs of R&D and the concerted effort of organizations (private and public agencies). It is evident that these factors were crucial to the rapid expansion in the "community" of conservation cropping practitioners during the 1990s. The future well-being of the new culture of agriculture will be conditioned by the extent of the following actions.

1. *Maintain positive environmental conservation policies.*

It is clear that the coupling of policy support for sustainable agricultural practices and cross-compliance has been a major force for expansion of conservation cropping in the United States. Cross-compliance, or some kind of regulatory policy, is particularly effective at the margins, where the choice between the new conservation culture and plow culture is most nearly even in economic respects. Regulatory policy is not needed where conservation culture is economically profitable, and it is not necessary where conservation culture has become conventional. In the latter case, informal social control mechanisms within the community of practitioners tends to enforce compliance with accepted cultural practice. However, along with policy support for sustainable agriculture research and practice, positive regulation demonstrates governmental commitment and encourages farmers as well as responsible governmental agencies to develop and maintain farm conservation plans, thereby keeping resource conservation at the forefront of farm planning.

In Australia, the successes and failures of Landcare policy has been much debated (e.g., Lockie and Vanclay [1997]). Although it has succeeded in engaging both farmers and non-farmers in important environmental issues, thereby heightening environmental concern, its impact on advancing conservation cropping culture seems to be limited

at best. The emphasis on whole-farm planning has rarely had improving soil and water conservation as one of the central objectives. Moreover, the linkage between the necessary technical advisory services and Land-care groups has not been strong enough to ensure adequate advisory inputs. It seems clear that to strengthen the spread of the new conservation cropping culture in Queensland and Australia, policy initiatives in the future should foster stronger linkages both with the commodity research and development corporations, the organizations and agencies providing technical artifacts and advisory services, and the community of farming practitioners.

*2. Increase investments in R&D dealing with conservation tillage and cropping.*

Public support for agricultural research in the United States has been declining, and this threatens to weaken the ability of R&D institutions to address recurrent constraints to satisfactory practice of conservation cropping as well as to sustain its advance into new areas and crops. The opportunity to increase the efficiency and effectiveness in conservation cropping technology is still very large (e.g., see Hatfield et al. 1998; Frye and Pierce 1998; Lal 1999), and these possibilities cannot be realized without sustaining the research commitment.

Compared to the United States, Australian and Queensland investments in R&D are very low. Although the recent Queensland initiative to establish the Farming Systems Research Institute is a step in the right direction, it is not sufficient, especially in focusing research on constraints in conservation cropping. The conclusion of a recent study emphasizes, “[f]or landholders to act on a significant scale, they must have access to proven, acceptable management strategies and technologies and be able to cope with the challenges of farming both profitably and sustainably within current economic and environmental constraints” (Hassal and Associates 1997, 112). The conservation tillage revolution demonstrated that when farmers recognize the need for a “better way” and have notions of what this might be, they need research and advisory system support in order to construct successful new conservation management systems. The possibilities of improving the practice of conservation cropping in Australia are not less than those in the United States.

*3. There is need for a paradigm shift among R&D agencies.*

Conservation tillage and cropping is practiced by farmers who must integrate diverse technologies into successful operating systems. The single-discipline technology and transfer approach used during the

green revolution is outmoded and should be replaced by a farmer-focused farming system approach to more effectively assist farmers. In this respect, a new R&D planning frame involving farmers and other stakeholders in R&D can yield dividends in developing adaptive techniques. Stakeholder participation in conservation technology development can be especially useful. More or less formalized networking between researchers and clientele is an important and common means of stakeholder participation in R&D. However, there is often need to make this a more formalized part of research and technology development planning. The Participatory Action Management (PAM) Model (Chamala and Mortiss 1990, 1995) can be adapted to a wide range of R&D program situations. Producer-initiated conservation tillage action research along the lines of the Horticultural Research and Development Corporation-funded Do-Our-Own-Research projects (Hunter et al. 1996) can be useful in helping to solve complex conservation tillage problems.

4. *Increase governmental support of extension advisory services.*

Governmental support of extension agencies, like that for research institutions, has declined. In consequence, the number of advisory personnel has been reduced, and the responsibilities of the remaining personnel have broadened. Both developments diminish the effectiveness of advisory personnel in maintaining the networks and informational linkages essential for providing adequate advisory assistance to farmers on conservation tillage and cropping. Lack of satisfactory training in agricultural economics and/or agronomy handicapped many professional advisors in the United States, as well as in Australia. Farmers' lack of expertise in using herbicides effectively continues to be a major constraint in the construction of conservation tillage systems. To fill the vacuum in declining numbers of farm advisors, farmers increasingly rely on private consultants. For many farmers, however, the additional cost of a private consultant is a deterrent to acquiring the assistance necessary to practice conservation cropping effectively.

5. *Improve the coordination among governmental agencies focusing on agricultural production and natural resource conservation.*

Progress in the innovation and reconstruction of tillage systems in the United States and Australia was slowed by differences in organizational cultures, interagency competition, and lack of a shared agenda and common conservation priorities. The splintering of research agendas, such as among commodity research corporations, increases the need for integrative mechanisms and processes. Integration needs to occur on

several levels—policy, program, and product or service—to most effectively meet the needs of farmers operating complex conservation cropping systems. Sustainable agriculture and resource use, for example, is a policy goal that provides a unifying focus for various research organizations. Coordination or complementarity of objectives aids integration of programs. The use of PAM-type models provides a mechanism to enable agencies to improve coordination in the absence of super-ordinate administrative directives.

6. *Find ways to increase support of nongovernmental agencies promoting conservation tillage and cropping.*

Nongovernmental entities, such as the CTIC in the United States and the Conservation Farmers, Inc. in Queensland, provide valuable informational and networking services supporting the new culture of agriculture and its adherents. Organizations, such as the Western Kentucky No-till Association, bolster local interest and commitment to conservation tillage and cropping. Specialized publications, such as *No-till Farmer* in the United States and *Farming Ahead with the Kondinin Group* in Australia, distribute timely news and information about developments in conservation farming. All of these means are important parts of the “organizational technology” of conservation cropping, which help maintain its continual reconstruction, thereby keeping it sustainable.

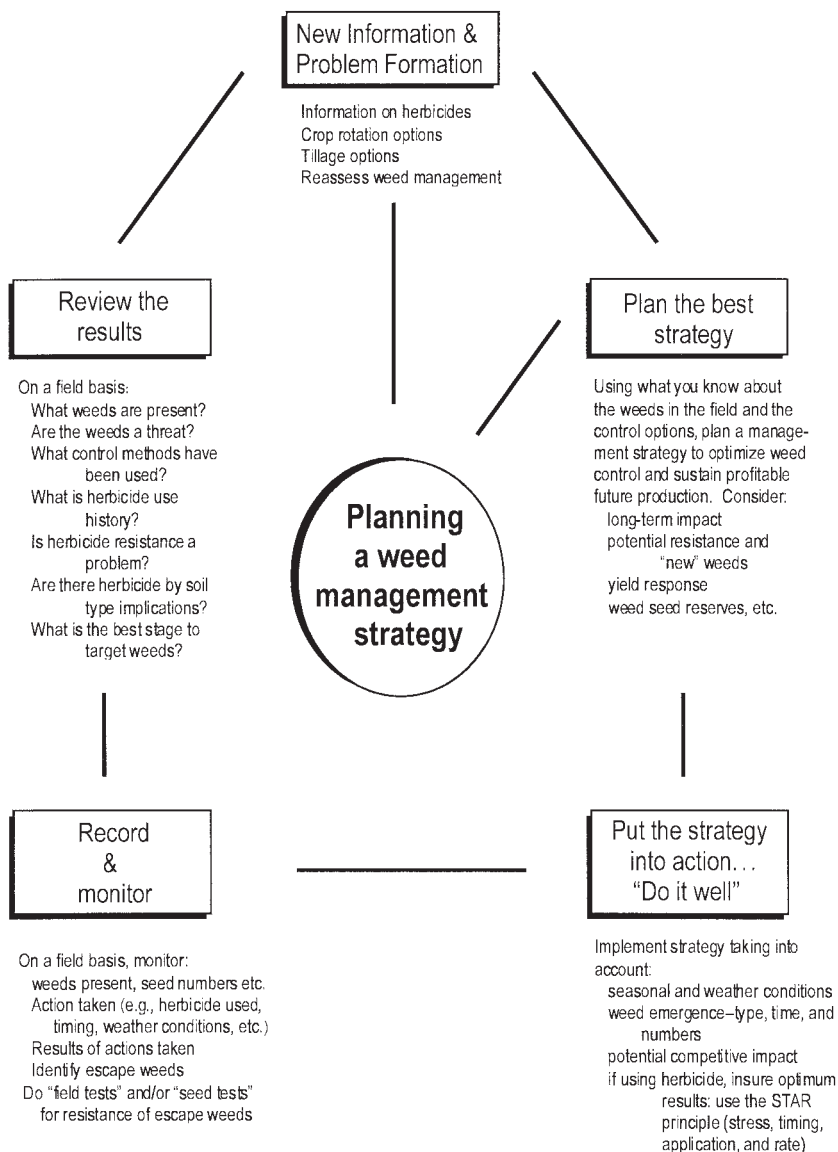
7. *Use various tools to understand factors affecting conservation tillage practice.*

Factors affecting the course of development—retrenchment or rapid growth—frequently change. The advocacy or promotion of systems change requires understanding of clientele as well as of possible triggering events. For example, wet seasons trigger consideration of alternative weed control and/or planting methods. Studies of individual farmers help to understand triggering mechanisms.

The collection of data on tillage practice by CTIC is invaluable in helping understand where conservation cropping is spreading and why, or where, there is retrenchment, signaling difficulties that need to be understood and addressed. The lack of such data for Australia is one of the most significant gaps in knowledge about conservation cropping. Without it, accurate assessment of progress or retrenchment in conservation cropping, goal setting, or targeting is very difficult, if not impossible.

Sample survey is a useful means of obtaining needed data on the current situation and of understanding the factors affecting performance of conservation cropping practice. Collaboration with officials in local

Figure 10.2. An integrated approach to weed management. Adapted from GRDC, 1997.



and global networks provides opportunities to collect data that facilitate innovation management and decision making. Chamala et al. (1999) review these methods.

8. *Follow action-learning approach with local networks to facilitate reconstruction of conservation tillage.*

The case studies indicate that farmers achieved successful reconstruction of conservation tillage systems through a process of action-learning. Working through this process while participating in local networks greatly facilitated learning a new tillage frame and adapting it to their specific situation. Group facilitation of the action-learning process can be established with formally organized as well as informal groups.

The general model of action-learning through experimental activity was presented in figure 2.5. An illustration of the use of an action-learning model applied to the problem of integrated weed management is presented in figure 10.2. The overall weed management process uses mechanical, cultural, chemical, and biological methods. Farmers have to make observations, acquire information and formulate the problem, and plan and implement a management strategy.

## Notes

1. See chapter 9.
2. Unlike the close link between teaching, research, and extension in U.S. Land-Grant Universities, academic teaching and research in Australian universities is not organizationally connected to the research and extension functions for the agricultural industry performed by DPI. The University of Queensland social scientists served under contract with DPI.
3. The team consisted of S. Chamala (University of Queensland), Bob Bateman, Doug Graham, Greg Cassidy, and Ken Keith (DPI) (Chamala et al. 1984).
4. Stakeholders have been brought into the R&D process through application of the PAM model developed by Chamala (1995) and Chamala and Mortiss (1990).



# 11

## The New Agriculture of Conservation Cropping: Present and Future

*There is . . . no universal prescription for the adoption of conservation tillage to any one location or region.*

—M.R. Carter (1994c, preface)

Plow culture flowered in an era when power and brawn were more important to farming success than calculation, practical experience was more important than science-based understanding, diversification was more important than specialization, self-sufficiency was more important than interdependence, land policy was more important than commodity or soil and water policies, and the community was more important than transnational corporations. Plow culture embodied a relatively simple technology with many options for dealing with environmental conditions and risks. It embraced relatively elementary principles of soil management and cropping, which were nonetheless effective and relatively efficient. It was a technology that required observational sensitivity, thoughtfulness, and practice in attaining mastery, but technological operations were easily comprehended. It was the technology of the husbandman, and the husbandman and head of a family were embedded in community (Berry 1977). Plow culture, especially where it is incorporated in a profitable, diversified farming system, with terraces, strip crops, pasture, hay, and legumes to protect and rebuild the soil, undergirds farming systems that have been and are sustainable in many parts of the world. But, for the production of many commercial crops, it is wasteful of soil, water, economic, and human resources, and in cropping areas it has been replaced by more efficient and conserving tillage systems.

Conservation tillage and cropping, as Nelson (1997, 72) pointed out, has “accommodated both the ideal of soil conservation and the incipient system of production agriculture after World War II.” Although conservation tillage has been rooted in an industrial model, utilizing the

more potent production inputs, it is also a radical reaction to the resource costs of industrial plow agriculture. With greater use of chemical fertilizers, high-yielding varieties, and larger, more powerful machines, farmers after World War II began to achieve greater and greater production efficiencies—at the expense of one of the most precious resources, the soil. But, the postwar decade also witnessed innovations in chemical weed control and notions of radically different tillage systems that in innovative networks of farmers and professional advisors spawned new conservation tillage, cropping, and farming systems.

Since then with these new systems and their varied adaptations, farmers have created a new and different landscape over broad areas of the United States, Australia, and other parts of the world (Carter 1994b). In favorable grain-growing areas of the Midwest and great plains, which once were dotted with houses, livestock barns, pastures, and clean-plowed fields or growing crops in fields surrounded with fencerows, one now sees open cropland covered with growing crops or crop residues and here and there a farm house, an equipment shed, and a few glistening, steel grain storage bins. Less noticeable to the discerning eye, perhaps, but of equal importance, the once commonplace gulleys, which furrowed every newly cultivated field, are now rarely to be seen. They are held in check by crop residues or are covered with grass in set-aside acres. The streams, once silt filled with each new freshet, are less filled with the land's wealth but more heavily burdened with chemical residues from the wider expanse of managed cropland.

The changed landscape of the countryside is only partly due to the revolution in conservation agriculture. To a large extent, a twenty-first century countryside would feature wide areas with growing crops and scattered farmsteads even if plow culture were still the prevailing practice. The greater land efficiency achieved with the new tillage cropping systems contributed only a small part of the comparative advantage of commercial grain growing over forage crops on Class I and II land, which drew farmers into specialized grain growing. The labor saved through conservation tillage cropping systems, however, has enabled farmers to increase the size of their farms, which reduced the number of farmsteads in the countryside. Where conservation cropping prevails, however, the farm landscape differs as much in its inward qualities—the quality of its soil and water resources and the economic well-being of its inhabitants—as in its outward appearance. It is the protection and improvement of the latter that are the principal consequences of the radical cultural shift in the design and management of the farm landscape.

As chronicled in the earlier chapters, the redesign of the farm landscape per se was rarely the most important aim of farmers constructing

new tillage and cropping systems. Most often, the aim was more mundane, to save time and money, and thereby increase profitability. Nevertheless, it is equally rare that the effort to construct a new tillage cropping system was undertaken for economic reasons alone. Most often, the triggering experiences, especially among the early innovators, were in some way a discomfiting realization that unless they changed either their tillage cropping practices or their farming systems, they would continue to degrade their soil resources. To retain, and eventually transform, their cropping systems, the innovators set about changing their tillage systems. In Kentucky, Queensland, and southern Illinois, as Makowski et al. (1990) argued, the early construction of conservation cropping systems occurred where the "agroecological fit" was best (i.e., most economically advantageous considering the prevailing agroecological conditions and structure of incentives). Many later reinventors of conservation tillage cropping systems faced a somewhat different choice; either change their tillage systems or lose their governmental program benefits as well as their cropland. In this respect, farmers everywhere have set about constructing new conservation tillage systems when the politicoeconomic agroecology made them the best fitting alternative to plow culture. Put otherwise, when the structure of incentives was favorable, farmers have responded by becoming co-partners with agricultural scientists and industry in building new sociotechnical systems of cropping agriculture without the plow.<sup>1</sup> The new agriculture has resulted in a 30 percent reduction in soil erosion in the United States and improved soil organic matter (Allmaras et al. 1998).

The new conservation agriculture is technical, institutional, and normative in its scope, and in this respect it constitutes a new technocultural system (Constant 1987). "Current conservation tillage systems," as Allmaras et al. (1998, 107) put it, "represent the merging of many necessary technologies, including the development of (a) high producing crop cultivars, (b) [tillage/planting] machinery systems . . . , (c) a set of principles required for operation of tillage system to achieve soil and water conservation, and (d) pest (weeds, diseases, insects) control by means other than tillage alone." The change in the technical routines using new machines to control weeds and pests, incorporate fertilizer, and plant crops, and leave crop residues, or cover crops, on the soil surface, are the most visible aspects of this new agriculture. Equally as important as the technologies to the new conservation cropping agriculture are the institutions (applied science laboratories, extension and conservation services, media, professional advisory services, input markets) that create, deliver, merge, and sustain farmers in the operation of their new sociotechnical systems. The processes of adaptive learning by

farmers, through which the new agriculture was created and is sustained, have occurred because of the linking of the local networks of innovative farmers and professional advisors with global networks of scientists and the sources of new chemical and mechanical technologies. The flow of information has not been one-way (i.e., top down). Instead, the construction of the new agricultural systems involved not merely the "reciprocal and mutually reinforcing" activities of farmers and scientists (van Es and Notier 1988), but, more importantly, these networks of relationships constituted the locus of innovation. These networks of innovation did not just happen. They were constructed through the intentional action by farmers and advisors who were seeking resources and ideas for construction of new tillage and cropping systems.

The new agriculture of conservation cropping is still expanding and developing in the United States and in Australia as well as in many other countries (Carter 1994a). There are not one but many conservation tillage cultural systems. Each type of tillage cropping agriculture ranges over the performance of specific crops with stubble mulching, strip and ridge tillage, no-tillage or direct drilling under the general climate, soil, weed, and types of residue conditions of a particular agroecosystem. Each tillage system is being continually modified. Issues of sustainable cropping have led to a rapidly expanding literature on chemical infiltration and transportation as well as the standard concerns with losses of soil and water.

The desire to minimize (conserve) use of chemicals in conservation tillage systems has led to experimentation with new management tools, such as the spatial distribution of yields and the precision application of nutrients and the spatial distribution of specific weed species and varying herbicide treatments. The expanded applied knowledge of conservation tillage and cropping provides increasingly specific guides as to the expected crop performance outcomes within specific agroecosystems even though substantial knowledge gaps remain (Carter 1994b; Hatfield et al. 1998; Pierce and Frye 1998).

The variation in conservation tillage cropping agriculture along the dimensions of soil, climate, crop conditions as well as national institutions and policies divides the applied science of conservation tillage into knowledge by nation and broad agroecological zones (Carter 1994b) (e.g., "humid microthermal climates"). However, this constitutes only the upper layers of the pyramid of cultural knowledge, which becomes wider and wider as it becomes increasingly localized and takes into account more and more constraints of soil types, climatic variation, weeds, and crops. At subagroecosystem levels, the availability of important sources of chemical and machinery and institutional inputs, as well

as farm location in specific watersheds, soil types, and pest (weeds, diseases, and animals) biota become critical constraints. Ultimately, the effective local knowledge of conservation tillage and cropping is the operational knowledge shared by farmers in farming communities. Because of the burgeoning constraints, the functional knowledge of conservation tillage and cropping systems, although suffused with modern science, is specific to place.<sup>2</sup>

The vertical and horizontal content of the local knowledge of conservation tillage distinguish it from what was formerly conventional plow agriculture. Imbedded in local knowledge systems of conservation cropping are notions of soil health and quality, and their causal factors and cropping implications (Romig et al. 1995). When plow culture reigned, these concepts and perceptions were the province mainly of avant-garde ecologists and rarely, if ever, the concerns of ordinary farmers. Wisconsin farmers, for example, believe that a wide range of soil, water, plant, and animal properties characterize a healthy soil. The most important properties of healthy soils, in their view, are its organic matter, plant growth, lack of erosion, earthworms, drainage, tillage ease, structure, pH, soil test adequacy, and crop yield. Healthy soils, as farmers see them, have loose, soft, crumbly textures, are darker, smell sweetly earthy, and are not crusted or compacted. Unhealthy soils have generally opposite qualities. These farmers recognize that overuse of chemicals, "poor" tillage practices, and lack of crop rotations can harm soil health, whereas fertility and conservation management, strategies that have arisen with the maturing of the soil conservation movement, improve it.

McCallister and Nowak (1999) have found that most Wisconsin corn growers use differences in soil texture, fertility, and organic matter, along with a variety of other indicators, such as drainage, to detect variation in soils requiring different application rates of herbicides, fertilizer, and manure. They conclude that these farmers "have a decent understanding of surface soil characteristics associated with crop productivity" but lack "a good understanding of the whole-soil mechanisms that influence long-term soil quality for sustainable crop productivity" (McCallister and Nowak 1999, 187). This conclusion is consistent with the way in which conservation cropping innovators in Kentucky and Queensland express what they are trying to do with their land in order to improve it for crop production. This includes the belief that leaving residue on the surface increases the organic matter, improves water infiltration and fertility, reduces erosion of their soils, and inhibits weed emergence. In cooler and wetter areas, techniques to provide quicker drying and warming become important. Farmers attuned to a new conservation tillage culture have learned to monitor soil health conditions, especially the

wetness/dryness, pH, and residue conditions, which affect the effectiveness of herbicides and other chemicals and crop productivity.

The expansion of local conservation tillage knowledge in temperate agroecosystems has enabled farmers, while conserving soil and water resources, to change cropping systems substantially in several ways. The most important of these changes is the establishment of continuous cropping. With conservation tillage, it is no longer necessary on many fields, as it was under conventional tillage, to rotate cropping with hay or pasture to protect the land from erosion and to build fertility. Rotations of crops or crops and cover crops, however, may be desirable under conservation tillage for the management of weeds and diseases or other purposes. Where the climate is favorable, the savings of moisture and planting time permit the expansion of double cropping.

The local cultures of conservation tillage and cropping also include new knowledge of weed and plant disease vectors. Farmers sharing conservation cropping cultures understand that in shifting from plow culture to mulch and no-tillage systems weed populations change. In particular, the substitution of chemical for mechanical control favors greater dominance of winter annual and perennial weeds and grasses. For most farmers, achieving adequate weed and pest control has been the biggest constraint to the successful operation of a reduced tillage, especially no-tillage. Successful management of these constraints often require the adoption of several chemical and mechanical pest control strategies. Innovative farmers often combine different weed management options with alternative crops in rotations to control different pests. Shared local knowledge of pest management continues to grow as farmers gain experience with different chemical treatments, reduced tillage systems, and rotations.

Depending on the efficacy of linkages with global carriers of applied science of conservation tillage and cropping, local knowledge continually expands and becomes more effective as the applied science advances. At the same time, again depending on the efficacy of local-global networks, the emergent problems that cropping system managers encounter stimulate researchers to undertake new research and develop new technology. The systemic linkages among the research and technology development and delivery institutions, markets, and farm operators are no less important to the continued successful adaption of conservation cropping culture in its maturity than they were in its infancy.

The important advances in conservation cropping in the United States during the past decade would not have occurred, despite the increased understanding of the relevant systems, without the heightened consciousness of environmental concerns and the development of

appropriate regulatory policies. The widening concern with protecting the environment not only helped mobilize political support passage of the 1985 Farm Bill, but also enlisted the support of many farmers in accepting its conservation policy provisions. The policy impetus instituted by the 1985 Farm Bill and its successors had four notable effects. It gave direction to and mobilized the NRCS to provide advisory assistance to farmers in planning and implementing appropriate conservation tillage and cropping systems even as it provided an incentive to farmers to cooperate with and seek the assistance of advisory services in constructing operational conservation tillage systems. The enhanced focus on conservation tillage systems in attaining compliance also fostered cooperation and coordination of NRCS and CES advisory services. Finally, the expanding markets for new conservation tillage equipment and herbicides stimulated industry to develop improved planters and chemicals.

Whether appropriate regulatory pressure will be needed to sustain the future utilization of conservation tillage systems is still to be determined. Nevertheless, the success to date of the regulation of compliance with conservation requirements in the United States and soil conservation structures and practices on the Darling Downs, Queensland (Coughenour and Chamala 1989) lays to rest arguments that regulation is an ineffectual tool in dealing with conservation problems on farms.

The Australian experience in the development of soil conservation systems in Queensland reinforces several conclusions with respect to the diffusion of complex systems in general and conservation tillage systems in particular. First and foremost, neither the system of stubble mulching nor of no-tillage could be, or was, simply transferred from the United States to Australia. Although suitable for demonstration purposes, none of the equipment—tillers and planters—which was adapted to agroecosystem conditions in the United States, was well-suited to soils on the Darling Downs. All had to be substantially modified before successful conservation tillage systems could be constructed by Queensland grain growers. Useful knowledge of conservation tillage for the summer and winter crops had to be developed by innovative farmers and farm advisors locally, that is, the knowledge and practice of mulch tillage had to become indigenous. In this cultural development process, the networking of farmers and advisors was equally as important in Australia as it was in the United States.

In much of the United States and Australia, conservation tillage cropping has now become the conventional component of a farmer's role. The significance of this, of course, depends on the type of farming system. That is, conservation tillage cropping may be practiced, for



example, by a farmer in raising corn for his livestock on a farm with tobacco produced with a plow and cultivator as well as by a farmer with hundreds of acres of corn and soybeans and no livestock or other crops. In the latter case, the culture of conservation tillage cropping clearly occupies a far larger space in his role as a farmer than in the former. In areas where farming with conservation tillage cropping is practiced by most farmers over a wide area, it becomes the dominant culture of farming as well as the predominant role of farmers. It is the dominant culture of cropping for farmers in nine states and Puerto Rico and for a substantial proportion of farmers in six more states, mainly the Appalachian, midwestern, and northern Great Plains regions.

As a farmer's relationships with others in local-global networks expand and intensify in the construction and maintenance of conservation tillage agriculture, the farmer becomes committed to a conservation tillage role in local society and inevitably develops a corresponding personal identity (Stryker and Statham 1985; Gamson 1992). In other words, in raising crops under conservation tillage the farmer is not merely managing nature for personal ends but also doing the work of society, which is recognized and approved of both by others in work relationships and by society generally. The work role of conservation tillage cropping, which farmers have constructed and to which they have become committed, has thereby engendered a new collective identity. Within the local-global networks of farmers, advisors, and scientists sharing the culture of conservation cropping, the image of an independent, brawny, plowman turning his sods is a rejected, romantic, and faded memory. The new identity of the conservation-cropping farmer embodies the idea of practicing sustainable agriculture and has been constructed around the image of a practical agroecologist. The keys to the new identity are twofold. One is an acceptance of the philosophical idea that the farmer himself is central to the agroecology of the farm. He is an integral part of the system, not above or outside it, but rather its focal axis and responsible for its care as well as its products. Moreover, the farmer and his farm are not isolated, but rather recognized elements of a larger, and very complex agroecological system. A self-conscious agroecological identity is therefore more holistic, and in this sense radically different from the image of the farmer exercising mastery over nature in the service of his economic ends that plow culture fostered.

It is an identity, however, that recognizes both relationships and limits. The farmer agroecologist is both dependent, for example, on naturally occurring processes (e.g., seasonal rhythms), and adapts his production systems to them. It is an identity that incorporates a substantial understanding and reverence for the natural ecosystem processes of



soil formation and protection, plant regimes, hydrologic cycles, and the like, as well as enthusiasm and enjoyment in constructing operating systems to enhance these processes for the production of economic crops.<sup>3</sup> Although farmers have historically gained personal satisfaction from growing crops, farmers engaged in successful conservation tillage and cropping have acquired a far greater practical understanding and management of agroecosystem processes and their part in these processes.

The other aspects of farmers' agroecological identity have not much changed. He makes a living from management of the socioeconomic and natural resources. In this respect, he is variously an owner, renter, borrower, customer, client, and salesman of agroecosystem resources and products.

### The Future of Conservation Cropping Systems

Conservation tillage and cropping agriculture at the farm level have developed and spread in the United States, as well as in Australia, along with the development in each case of a web of linkages, connecting farmers with research and advisory institutions, markets for technological inputs and farm products, and agencies implementing governmental conservation policies. It is common practice for social scientists to think of the change in tillage and cropping systems as the adoption by individual farmers of new technologies that are caused, or brought about, by various personal, farm, economic, institutional, and policy factors. However, we have stressed the point of view that the new conservation-cropping agriculture is a sociotechnical complex, centered on local knowledge of successful, cropping systems by farmers in local networks. In this sociotechnical complex, however, the local culture is linked with policy-implementing agencies and centers of scientific knowledge and technology development (Constant 1987). As van Es and Notier (1988) argued, the innovation of conservation tillage systems at the farm level has been an interactive process over time with trial and experimentation taking place on both farms and research stations and with problem identification, innovative ideas, and techniques flowing in both directions. In this respect, the new cropping agriculture in its varied agroecosystem manifestations is a "cultural product" of the total complex. Its present and future well-being as agricultural practice thus depends, as was suggested in chapter 10, on sustaining the total sociotechnical complex—the policy, knowledge and technology, agency, and markets—that contributed to its initial innovation and eventual spread. In the present context, we can do little more than highlight some of the issues.

The conservation provisions of the 1985 and 1990 Farm Bills substantially succeeded, where earlier conservation policies in the United States had largely failed, to encourage farmers to make the human and financial capital investments necessary to adopt soil- and water-conserving systems, including conservation tillage and cropping systems. Implementation of the cross-compliance policy, for example, contributed to the quadrupling of no-till acreage between 1990 and 1998. The part played in the decisions to adopt no-tillage cropping by the gain in information about soil losses and conservation cropping practices obtained by farmers through consultation on farm conservation plans has been overshadowed by the attention paid to the role of compliance regulation. It is true, of course, that the openness to additional information about conservation tillage itself may have been largely motivated by the threatened loss of program benefits. The conclusion, however, seems inescapable that many farmers, for whom the possible cost-benefits of no-tillage formerly had seemed too small, or too risky, were persuaded to make investments in conservation tillage systems to avoid losing a valued entitlement.

Implementation of the compliance provisions of the 1985 Farm Bill, however, has had several effects that in total are more important than the increase in farmers' motivation to practice conservation tillage, which the threatened loss of benefits aroused. The larger impact of this process is its importance for sustaining conservation cropping in the long run. Already mentioned, of course, is the importance of the implementation process in increasing the fund of local knowledge about the extent of erosion and of conservation tillage. Of equal importance, the implementation process established conservation tillage methods as the normative cropping system(s) in erosion-prone areas. This has the effect not merely of increasing both the spread of information through local networks and magnifying the legitimacy of conservation tillage systems locally, but also of empowering local structures of social control, which operate to constrain farmers from deviating from their farm conservation plans. Finally, it brought the major governmental agencies within the same sociotechnical frame and organizational system with respect to the support of farmers practicing conservation tillage and cropping. This combination of local, social, and institutional support and constraint provides potent mechanisms for sustaining conservation cropping in the long run.

Over time, most farmers adjust their cropping and farming systems to take advantage of the greater efficiencies of conservation cropping systems. Moreover, they recognize that soil quality and productivity have increased. Once this has occurred, a return to plow culture cropping sys-

tems is neither desired nor economically feasible. Over the longer term, therefore, regulatory incentives to conservation tillage and cropping are probably unnecessary.

The initial experiences of farmers with innovative conservation tillage systems almost invariably included difficulties with weed and pest control and seed placement. In the past, this often led the farmer to a partial, or in some cases, a complete return to plow agriculture. Unproblematic initial experiences of new users of conservation cropping systems should not be expected despite the advances made in the science and technologies of residue retention and management. Indeed, the possibilities of tillage system retrenchment have been anticipated in farm plans that permit periodic use (e.g., once every 3 years) of plow tillage methods as long as the average soil loss, with the tillage systems used over a period of years, does not exceed a specified level. A resolute commitment to conservation tillage systems and to solving the problems that inevitably arise almost invariably contributes to a growth in managerial competence sufficient to sustain the successful operation of a conservation tillage system. It is during the initial tillage system adaptation and learning phase that implementation of appropriate agency programs and policy incentives are especially important. Sustaining and expanding the advance made by the new practitioners of the craft during the 1990s will depend on sustaining farm conservation planning and technical assistance during the retrenchment phase of the new agriculture.

The culture of conservation tillage cropping is continuing to evolve, which is to say that new problems continually arise that require the development of new knowledge and adaptive techniques (e.g., Pierce and Frye 1998; Duffy 1998). Although the development of the scientific knowledge and techniques of conservation tillage has been a notable characteristic of the new agriculture, its future vitality will equally depend on sustaining its dynamic, problem-solving quality. This is due to the continual evolution of agroecological and socioeconomic conditions, which raise new questions requiring solutions. Sustaining the advance of the new agriculture, as well as its continued expansion, thus is highly dependent on sustaining the research and technology development of conservation tillage and cropping. Although many new techniques can be delivered in conventional ways, it will also be important for agricultural advisors to keep alive network relationships and the mechanisms of adaptive-learning required for a locally adaptive conservation cropping agriculture.

In the early years of the development of conservation tillage, farmers had to develop their own equipment, often with the assistance of local machinery firms or agricultural engineers, because the major machinery

companies were only interested in conventional plows and tillage equipment. However, this attitude changed as farmers' interest in conservation tillage increased and demand expanded. Now farmers have a broad range of choices in selecting appropriate conservation tillage equipment. Meanwhile, chemical companies have continued the development of more effective herbicides and insecticides. The results, however, have been mixed. Although new chemicals have provided weed control, some weeds have developed chemical resistance, and some chemical residues have shown up in ground water. A long-run solution to making conservation tillage systems more sustainable, especially with respect to water quality, is likely to require development and adoption of weed "management," by contrast with the currently prevailing weed "control" approach (Duffy 1998). Development of weed management strategies is based on better understanding of weed ecologies and system management strategies. The cooperation of chemical companies in such an endeavor will be important to its ultimate success.

## Notes

1. Allmaras et al. (1998, 144) conclude: "there is now almost complete farm use of tillage systems without the plow" to produce wheat, corn, and soybeans.
2. In this sense, the local and operational knowledge of conservation tillage systems is analogous to the local knowledge of rotational grazing described by Hassanein and Kloppenburg (1995).
3. For farmers, "interesting work," "pleasant physical surroundings," and the opportunity to develop one's abilities are the three most important sources of noneconomic rewards of farming (Coughenour and Swanson 1988).

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## Acronyms

AB	Agricultural Branch
ACP	Agricultural Conservation Program
AEH	Area of Erosion Hazard
ARS	Agricultural Research Service
ASA	Australian Society of Agronomy
CES	Cooperative Extension Service
CFIC	Conservation Foundation Information Center
CRP	Conservation Reserve Program
CTIC	Conservation Technology Information Center
DOOR	Do-Our-Own-Research
DPI	Department of Primary Industries (Queensland)
ERS	Economic Research Service
EQIP	Environmental Quality Incentives Program
FCP	Farm Conservation Plan
FSA	Food Security Act of 1985
GRDC	Grains Research and Development Corporation
LWRRDC	Land and Water Research Development Corporation
MEC	Machinery Evaluation Committee
MLA	Meat and Livestock Research and Development Corporation
MTC	Machinery Testing Committee
NLP	National Landcare Committee
NRCS	Natural Resource Conservation Service
NSCP	National Soil Conservation Program
NSW	New South Wales
PAM	Participative Action Management
PIK	payment-in-kind
PMP	Property Management Planning
RCA	Soil and Water Resource Conservation Act of 1977
SCA	Soil Conservation Authority (Queensland)
SCB	Soil Conservation Branch
SCS	Soil Conservation Service

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